FOOD PLANTS OF *MELANOPLUS FEMURRUBRUM FEMURRUBRUM* (DEGEER) IN THE BLUESTEM GRASS REGION OF KANSAS

by

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INTRODUCTION

The species of grasshoppers in a given area and their populations are determined to a considerable extent by food plants. Food preferences and relationships of grasshopper species and plant species in pastures of the Great Plains are not well understood.

Cage studies on plant food preferences are one of the current phases of the grasshopper project which has been in progress since 1957 and is part of Regional Project NC-52 on factors influencing the distribution and abundance of grasshoppers. The Kansas portion of the project involves a study of a series of habitats within a bluestem grass range, the Donaldson Pastures, near Manhattan, Kansas. Nine pastures, each under different experimental treatments, are studied. Three of these pastures are included in an intensity-of-grazing treatment, three in a deferred grazing treatment and three in a time-of-spring-burning treatment. Range sites within each of the nine treatments are: limestone breaks, ordinary upland, and clay upland. Arnett (1960) was the initial investigator. Largest grasshopper populations were found on the early spring burned and the heaviest grazed pastures. Lightly grazed pastures and those grazed under a deferred-rotation practice had the smallest populations. Clay upland sites, and to a slightly lesser extent ordinary upland range sites, supported larger populations than the limestone breaks. His study was intended to be exploratory in nature. A better understanding of grasshopper behavior, particularly in regard to feeding habits and preferences, and association with plants, was considered the next step.

This report describes results of cage studies on plant preferences of *Melanoplus femurrubrum femurrubrum* (DeGeer), conducted during the growing season of 1961. Two other species were studied: Melanoplus differentialis (Thomas), and Phoetaliotes nebrascensis (Thomas). Further data for M. f. femurrubrum (DeGeer), not presented here, along with that for the other two species, will be presented as a minor portion of the Ph.D. dissertation when more data are available.

REVIEW OF LITERATURE

Literature accounts of grasshoppers are probably more numerous than for any family except possibly mosquitoes.

Although much of the literature includes general references to adult lists and associated habitats, relatively little exists on explanation of relations of habitat to species distribution. Specific studies on association between grasshopper species and range plant species are limited in Kansas and occur only to a limited extent elsewhere. Woodruff (1937) did a survey of the grasshoppers inhabiting the native grasses in Kansas. Shotwell (1939) summarized the species according to habitats. Wilbur (1936) reported on the injury to the heads of native grasses and Wilbur and Fritz (1940) studied the populations present in typical pastures of the bluestem region of Kansas. Smith (1954) assembled and analyzed information on annual fluctuations of grasshopper populations in Kansas over a 100 year period from 1854 to 1954. One conclusion of his study of the relation of climate to grasshopper populations was:

> While the numbers of grasshoppers each year must be dependent in some way on the kind, amount, and quality of natural food available to them and their parents, modified directly by the weather as from dashing rains and by the extremes of temperature, and indirectly as weather affects plants, parasites, predators and diseases, the data available on food do not permit a correlation to be made with grasshopper populations.

It is generally accepted that plants, directly or indirectly, influence the size of grasshopper populations. Isley (1937) stated that plant distribution and the extent and vigor of plant growth are definitely soil-related, and soil make-up is a determining factor in the choice of egg laying sites by many species. He therefore considered soil as the primary controlling environmental factor in local distribution and plants and vegetative soil cover, as they are related to food, protection, temperature, and humidity in the microhabitats, as indirectly significant. The plants chosen as food vary between different species of grasshoppers, and all the plants present in any chosen location are not necessarily used as food plants. The old belief that grasshoppers will devour everything that is green has been accepted by many authors but was originally applied only to the "Rocky Mountain locust", Melanoplus spretus Walsh, (Riley, et al., 1877). Work by Criddle (1933), Isley (1937, 1938, 1944, 1946), Hodge (1933), and Sanderson (1939), showed that a large percentage of grasshoppers were associated with a restricted number of host plants. Other investigations on relationships of habitat to grasshopper distribution and host plant associations to various degrees include those of Hebard (1925, 1929, 1931, 1934a, 1934b, 1936, 1938), Uvarov (1928), Cantrall (1943), Pfadt (1949), Friauf (1953), Shotwell (1930, 1938), Ball et al. (1942), Anderson and Wright (1952), Barnes (1955), and Wakeland (1958). Some recent work, part of which is still in progress, includes population studies on Arizona desert, range, and cultivated land by Barnes (1959, 1961), and effects of grasshopper and management practices on short-grass rangeland (Nerney 1959, 1960, 1961). Using the technique of crop analysis, (Mulkern and Anderson, 1959; Brusven and Mulkern, 1960) Mulkern (1960, 1961) in North Dakota and Pruess (1960, 1961) in Nebraska are currently involved in food habit and preference studies with various grasshopper species.

Factors that affect a grasshopper's selection of host plants, from the many available, are too numerous to mention. Smith (1959) found that certain plants which are eaten are nutritionally inadequate to certain grasshopper species. Painter (1953) states that plants and different parts of the same plant may differ nutritionally and implies that this may be a possible explanation for some resistance in plants. In grasshoppers, however, the resistance seemed to be a preference phenomenon. A majority of the work on breeding for resistance has been and is being done with field crops (Painter 1951, 1953, 1960, 1961). Diver and Diver (1933) noted that degree of wetness, vegetation height, density and type of plant community are among the factors determining the distribution of species. Correlation between mandibular morphology and food plants (Isley, 1944) is important as an indication of general food habits. In certain cases a grasshopper species will feed on one plant, and during later development due to availability of plants or other factors, change food plants. This was the case with <u>Melanoplus bruneri</u> as reported by Kreasky (1960). Nymphs and adults fed heavily on lupine and timothy. Damage to timothy became especially noticeable as lupine became depleted.

Species differ in the amounts of food required. When considering economic importance of a particular species, amounts of food eaten by each individual must be considered. Gangwere (1959) noted that food consumption increases in direct proportion to size during the nymphal stages. Mulkern (1961) working in this area has developed a Plant Value Index based on palatibility of plants to cattle.

Many grasshopper species confine their feeding to a group of related plants and in a few known cases to a single plant species. As an example, Hypochlora alba (Dodge) is often cited as feeding only on Artemesia spp. Isley (1938), however, states that in cage tests H. alba will live for ten days supplied with broomweed and sunflower. It has been stated before, but bears repeating, that an understanding of the host plant relationships of all major species would contribute valuable data toward an understanding of terrestrial communities.

The work reported on here is considered a first step in obtaining clues as to preferred plant species which might be used in a correlation that exists in the association between grasshopper and plant species, particularly in the bluestem regions of Kansas.

MATERIALS AND METHODS

The initial evaluation of the associations between plant species and grasshopper species was approached in the following manner. The population density of each species of plant from each pasture treatment and range site within each treatment was obtained from the Department of Agronomy and corresponding data on population of each grasshopper species from Arnett (1960). Evaluation was made of each grasshopper species present in relation to numbers of each plant species present on (1) various soil types and pasture treatments; (2) the same soil type irrespective of pasture treatments; and (3) the same pasture treatment irrespective of soil type. Using a statistical formula, "Kendall's Tau" (Figure 1), (Siegel, 1956), rank correlation coefficients were determined. The insects and plants are ranked according to relative abundance of each species after combining collections of each of the three soil types for each of the nine pastures. For example, by looking at Figure 1, plant rank 8th is opposite insect ranked 1st. In the plant rank row only one plant ranks higher than 8th (9), so "1" is placed in the concordance row. Next, plant ranked 4th corresponds to insect ranked 2nd, and 4 is exceeded 4 times (by 9, 6, 7, 5), so "4" is recorded in the concordance row, and so on. Thus concordance is the number of ranks higher than the one being ranked. Discordances, on the other hand, are the number of plants in the row ranking lower than the one being ranked. There are 7 numbers below or less than 8 (4, 6, 2, 1, 7, 5, 3) so "7" is recorded as the discordance of the plant ranking 8th. Next, (for the plant ranked 4th) there are 3 numbers smaller than 4 (2, 1, 3), so "3" is recorded in the discordance row, and so on. As a check for errors, the following procedure is used: total concordance plus total discordance should equal 1/2N(N-1) where N is the number of pastures in which you have observations. Thus in the example in Figure 1, 12 + 24 = 1/2 x 9 x 8 or 36. Plates I - VI are submitted as examples of the rank correlation coefficients for the various treatments and soil types as they are plotted for each plant and grasshopper species. Coefficient range is from zero to a plus 1.0 or a minus 1.0. The plates are limited to plus or minus 0.9, however, since this was the highest correlation observed for any species. Detailed report on the correlation studies will be given at a later date in the Ph.D. dissertation in connection with a proposed crop analysis study. It is submitted here only because it was one of the methods used as a guide in determining which plants to use in food preference work.

Cage studies were conducted in an outdoor insectary which could be opened from three sides, thereby coming relatively close to outdoor temperatures (Plate VII). A water cooler was installed to maintain temperatures when necessary below 100° F. Each cage was composed of six compartments, 14" x 11 1/4" x 9 1/4", with removable glass fronts (Plate VIII).

The following plants were used (common names are those recommended by Anderson, 1961):

Perennial Grasses:

Asm	Agropyron smithii Rydb. - - - - - - - - -	western wheatgrass
Age	Andropogon gerardi Vitman - - - - - - - -	big bluestem
Asc	Andropogon scoparius Michx. - - - - - - -	little bluestem
Bcu	Bouteloua curtipendula (Michx.) Torr. -	sideoats grama
Kcr	Koeleria cristata (L.) Pers. - - - - -	prairie junegrass
Psc	Panicum scribnerianum Nash - - - - - -	scribner panicum
Pvi	Panicum virgatum L. - - - - - - - - - - -	switchgrass
Snu	Sorghastrum nutans (L.) Nash - - - - -	indiangrass
Scr	Sporobolus cryptandrus (Torr.) A. Gray-	sand dropseed

Perennial Forbs:

Ala	Achillea millefolium L. subsp. lanulosa (Nutt.) Piper - - - - -	western yarrow
Aps	Ambrosia psilostachya D.C. - - - - - -	western ragweed
Artem	Artemesia spp. - - - - - - - - - - - - -	sagewort; sagebrush
Ave	Asclepias verticillata L. - - - - - - - -	whorled milkweed
Aster	Aster spp. - - - - - - - - - - - - - - - -	aster
Keu	Kuhnia eupatorioides L. - - - - - - - - -	falseboneset kuhnia
Lpu	Liatris punctata Hook. - - - - - - - - -	dotted gayfeather

Ost   *Oxalis stricta* L. - - - - - - - - - - - - common yellow oxalis

Ppu   *Petalostemum purpureum* (Vent.) Rydb. - purple prairieclover

Pfl   *Psoralea tenuiflora* Pursh var. *floribunda* (Nutt.) Rydb. - - - - - manyflower scurfpea

Rci   *Ruellia humilis* Nutt. (R. *ciliosa* of manuals, in part; R. *caroliniensis* of manuals, in part) - - - - - - - fringeleaf ruellia

Sun   *Schrankia nuttallii* (D.C.) Standl. (S. *uncianata* of manuals, not Willd.) - - - - - - - - - - - - catclaw sensitivebriar

Sin   *Silphium integrifolium* Michx. (including S. *speciosum* Nutt.) - - wholeleaf rosinweed

Vba   *Vernonia baldwini* Torr. - - - - - - - - - baldwin ironweed

Annual Forbs:

Ael   *Ambrosia elatior* L. - - - - - - - - - - - common ragweed

Eca   *Erigeron canadensis* L. - - - - - - - - - horseweed fleabane

Woody Plants:

Aca   *Amorpha canescens* Pursh - - - - - - - - - leadplant amorpha

Cov   *Ceanothus ovatus* Desf. - - - - - - - - - inland ceanothus

The cage floors were lined with tinfoil and sand was placed in each, forming a slope approximately 1 inch deep in front and 4 inches deep toward the rear.

The plants were placed in water-filled plastic vials through a hole in the cap. The water kept the plants from wilting during the feeding period. Each vial was inserted into the sand equidistant from the screen, until the lip was level with the sand surface. This gave each grasshopper an equal chance to walk directly from the sand onto the chosen plant. Water for the grasshoppers was supplied by soaked cellulose cotton placed in petri dishes.

Twenty grasshoppers were placed in each compartment. An attempt was made to keep instars of the same age together when nymphs were studied. A spread of two consecutive instars was allowed in each cage; i. e., 2nd and 3rd instar nymphs in one cage, 3rd and 4th in another, etc. Since females of M. f. femurrubrum (DeGeer) may be easily confused with other Melanoplus some of the specimens were sent to the U. S. National Museum for confirmation.

After some preliminary experimentation and consideration of the various amounts of food required by different species, it was decided to use only two plant species in each cage. The question arose concerning the validity of this technique since in some instances, grasshoppers might be forced to make a choice between two undesirable plants. It is believed, however, that the results are probably valid since an attempt was made to pick out the most obvious desirable or undesirable plant species based upon the before-mentioned association studies. Changes will be made in subsequent studies, allowing more choices.

The grasshoppers were allowed to feed for 48 hours on each set of two plants. After 48 hours the plants were removed and replaced by another series of two plant species. Three replicates of each series were included. Species of grasses vs. grasses, and grasses vs. forbs, were evaluated. Photographs were taken of the plants immediately after removal from the cages. (Plates IX - XV). These plates are only representative to show the type of damage done; however, a complete photographic record of all three replicates was taken. The photographs were ranked according to the intensity-of-feeding as compared with before-feeding pictures. A grade of A, B, C and D was used: A = no feeding; B = trace to 1/2 of plant eaten; C = 1/2 plus eaten; D = eaten entirely. This intensity-of-feeding (IF) was graded for each series of plants. When replacement of a plant was necessary before the end of the 48 hour period, that replicate was automatically rated a "D", however, the plant was replaced to keep from forcing the grasshoppers onto the second, less preferred plant.

Counts of total numbers of grasshoppers resting (R) on the plants, and whether or not they were feeding (F) were made at 7 a.m., 12 noon, 5 p.m., and in some cases 10 p.m. during the 48-hour feeding period. Feeding was recorded when movement of the mouthparts was observed when in contact with the plant, and included in certain instances cases when the grasshopper was merely nibbling and did not leave any visible damage. A high resting count without feeding on a particular plant may indicate an association other than food preference. Temperatures were not recorded in the first few experiments. In subsequent studies room temperature was recorded during each observation. Results of counts are presented in tables 1 through 7. The abbreviations across the top represent the first letter of the genus and the first two letters of the species of plant, i. e., "Age" = Andropogon gerardi.

Plants and grasshoppers were obtained directly from the Donaldson Pasture area.

RESULTS AND DISCUSSION

Feeding data, which include degree of injury based upon (1) photographs of feeding on each plant and (2) numbers of grasshoppers resting and feeding on each plant, are presented in tables 1 through 7. Considerable difference is apparent between counts made for a given species on a given plant at various times during the day. When both plants read zero at a given time, all grasshoppers were perched either on the sand floor or screen sides of the cage.

Intensity-of-feeding (IF), as graded at the bottom of each series, generally match the resting and feeding counts. In certain cases a plant was graded "A", indicating from the photograph that it was apparently untouched, yet the count showed one or more cases of feeding. In other cases, little or no feeding was observed, yet the photographs indicated damage, indicating that feeding occurred at other times than when the counts were made.

Table 1 shows the results of big bluestem (Age), compared to 23 other plants, 11 of which were preferred over big bluestem as indicated by the higher resting and feeding counts during most individual observations. Each replicate was completely consumed in four instances (grade "D"). The average numbers of grasshoppers resting and feeding respectively on these four plants as compared to big bluestem were: aster (Aster) (9.0 vs. 1.0; 5.2 vs. 0.7); horseweed (Eca) (8.9 vs. 1.4; 4.2 vs. 0.4); common ragweed (Ael) (5.7 vs. 2.2; 2.6 vs. 0.1); and scurfpea (Pfl) (3.6 vs. 0.2; 1.6 vs. 0.0). The average numbers resting and feeding respectively on each of the remaining seven preferred plant species as compared to big bluestem, when based upon grading of injury, were: wholeleaf rosinweed (Sin) (7.4 vs. 0.4; 4.8 vs. 0.2); western yarrow (Ala) (6.4 vs. 0.4; 2.2 vs. 0.0); sagewort (Artem) (5.4 vs. 2.4; 2.7 vs. 0.7); purple prairieclover (Ppu) (4.7 vs. 0.2; 2.2 vs. 0.2); western ragweed (Aps) (4.5 vs. 0.7; 2.8 vs. 0.3); leadplant amorpha (Aca) (3.4 vs. 0.2; 0.8 vs. 0.0); and sand dropseed (Scr) (2.8 vs. 3.2; 1.8 vs. 1.0). Equal damage based upon grading compared to big bluestem was observed on fringeleaf ruellia (Rci), catclaw sensitivebriar (Sun), baldwin ironweed (Vba), indiangrass (Snu), scribner panicum (Psc), switchgrass (Pvi), and dotted gayfeather (Lpu). Big bluestem was preferred over falseboneset kuhnia (Keu), inland ceanothus (Cov), prairie junegrass (Kcr), little bluestem (Asc), and sideoats grama (Bcu). In no case was a "D" assigned to big bluestem and only two were rated "C+".

With reference to individual feeding observations, there was no definite time or sequence during which feeding occurred. However, it was obvious that fresh plant material was preferred. This accounts for the higher number present during the 5 p.m. count at the beginning of each new series. New plants were usually placed in the cages between 3 and 5 p.m. They were vigorously attacked as soon as the cage was left undisturbed. This was especially apparent in the 5 p.m. counts on the highly preferred plants such as common ragweed (Ael), horseweed (Eca), aster (Aster), and scurfpea (Pfl) (Table 1). Undesirable plants were also attacked shortly after being placed in the cage; however, they sustained little or no injury as indicated by the intensity-of-feeding (IF) as graded from the photographs. In most cases grasshoppers went directly to the desired plant; however, in a few instances it was observed that an individual grasshopper would jump onto a plant and shortly leave the plant without feeding and move to the other plant where vigorous feeding occurred, resulting in severe damage.

High counts which occurred at other times during the day, for example, 5 p.m. the second day for horseweed (Eca) and 7 a.m. for aster (Aster), in most cases were the result of the plant being consumed and replaced in one or more of the three replicates at that time.

Temperatures in Table 1 do not apparently show any trend or association with either a high or a low incidence of resting or feeding.

Subsequent tables do show, however, that at 60° F. or below, feeding was severely reduced and in most instances terminated.

Data in Table 1 were concerned with 2nd and 3rd instar nymphs except those on: inland ceanothus (Cov), indiangrass (Snu), prairie junegrass (Kcr), little bluestem (Asc), and sideoats grama (Bcu), where 3rd and 4th instar nymphs were used; and sand dropseed (Scr), scribner panicum (Psc), switchgrass (Pvi), and dotted gayfeather (Lpu), where adults were used.

Sand dropseed (Scr) as compared to 20 other plants is shown in Table 2. Grading indicates that eight plants were preferred over sand dropseed. Only one plant in this series, horseweed (Eca), was completely consumed in all three replicates (grade "D"). The average numbers of grasshoppers resting and feeding respectively on these eight preferred plants as compared to sand dropseed were: aster (Aster) (10.4 vs. 1.8; 5.6 vs. 1.4); dotted gayfeather (Lpu) (9.0 vs. 1.4; 3.6 vs. 0.6); wholeleaf rosinweed (Sin) (6.8 vs. 0.5; 3.5 vs. 0.5); horseweed (Eca) (5.8 vs. 1.7; 2.3 vs. 0.5); western ragweed (Aps) (4.4 vs. 1.8; 1.4 vs. 1.0); indiangrass (Snu) (2.8 vs. 1.6; 1.0 vs. 0.8); scurfpea (Pfl) (2.4 vs. 1.0; 0.8 vs. 0.8); and common ragweed (Ael) (1.4 vs. 3.4; 1.0 vs. 1.4). Equal damage based upon grading compared to sand dropseed was observed on sagewort (Artem), and baldwin ironweed (Vba). Sand dropseed was preferred over inland ceanothus (Cov), falseboneset kuhnia (Keu), purple prairieclover (Ppu), catclaw sensitivebriar (Sun), leadplant amorpha (Aca), little bluestem (Asc), common yellow oxalis (Ost), scribner panicum (Psc), prairie junegrass (Kcr), and sideoats grama (Bcu). In no case was a "D" grade assigned to sand dropseed and only one was rated "C" and two a "C+".

High average resting counts are noted for aster (Aster) (10.4), dotted gayfeather (Lpu) (9.0), wholeleaf rosinweed (Sin) (6.8), and inland ceanothus (Cov) (6.5) (Table 2). These four plants (three forbs and one woody plant) apparently were preferred resting sites. Although the numbers feeding on each increased correspondingly, the degree of injury remained relatively low.

Temperatures in Table 2 ranged from 48° F. to 99° F. No reduction in resting or feeding is apparent at high temperatures up to 99° . There was some reduction in numbers feeding at 61° F. although a high count remained for dotted gayfeather (Lpu). Below 54° F. all feeding terminated. Resting counts remained near normal at low temperatures compared to other temperatures, as indicated at 48° F.

Data in Table 2 were concerned with 3rd and 4th instar nymphs except those on: common ragweed (Ael), and leadplant amorpha (Aca) where 4th and 5th instar nymphs were used; and on dotted gayfeather (Lpu), scribner panicum (Psc), prairie junegrass (Kcr), sideoats grama (Bcu); indiangrass (Snu), little bluestem (Asc), and common yellow oxalis (Ost) where adults were used.

Switchgrass (Pvi) compared to 22 other plants is shown in Table 3. Grading indicates that 10 plants were preferred over switchgrass. Again only one plant in this series, western yarrow (Ala), was completely consumed in all three replicates (grade "D"). A grade is not available for sagewort (Artem) and horseweed (Eca). Accidentally the negatives were exposed to direct light and were not developed. The higher average resting and feeding counts as compared to switchgrass, (sagewort, 4.4 vs. 1.2, 2.4 vs. 0.4; horseweed, 7.0 vs. 0.4, 0.8 vs. 0.0) indicate that both were preferred. The average numbers of grasshoppers resting and feeding respectively on the 10 preferred plants based on grading as compared to switchgrass were: dotted gayfeather (Lpu) (12.0 vs. 2.8; 4.0 vs. 1.0); wholeleaf rosinweed (Sin) (7.0 vs. 1.7; 2.8 vs. 0.5); western ragweed (Aps) (5.0 vs. 1.5; 1.5 vs. 0.7); common ragweed (Ael) (4.8 vs. 1.6; 2.6 vs. 0.6); aster (Aster) (4.5 vs. 1.8; 1.0 vs. 0.3); western yarrow (Ala) (4.2 vs. 1.2; 0.8 vs. 0.2); scurfpea (Pfl) (4.0 vs. 1.2; 2.0 vs. 0.3); little bluestem (Asc) (2.8 vs. 3.8; 2.2 vs. 3.0); sand dropseed (Scr) (1.8 vs. 4.2; 1.0 vs. 3.2); and leadplant amorpha (Aca) (1.2 vs. 0.8; 0.7 vs. 0.3). Equal damage based on grading compared to switchgrass was observed on baldwin ironweed (Vba), inland ceanothus (Cov), and scribner panicum (Psc). Switchgrass was preferred over purple prairieclover (Ppu), falseboneset kuhnia (Keu), catclaw sensitivebriar (Sun), common yellow oxalis (Ost), prairie junegrass (Kcr), sideoats grama (Bcu), and indiangrass (Snu). In no case was a "D" grade assigned to switchgrass and only one was rated "C". No feeding was observed on three plants (Table 3): falseboneset kuhnia (Keu), switchgrass (Pvi vs. Eca) and catclaw sensitivebriar (Sun); however, in two cases where a grade is available, injury had resulted. Apparently this was not the effect of temperature since 76° F. was the low and 99° F. the high in this case. The highest resting count was observed on dotted gayfeather (Lpu) followed by horseweed (Eca) and wholeleaf rosinweed (Sin).

Data in Table 3 were concerned with 3rd and 4th instar nymphs except those on: common ragweed (Ael), and inland ceanothus (Cov) where 4th and 5th instar nymphs were used; and on little bluestem (Asc), sand dropseed (Scr), indiangrass (Snu), scribner panicum (Psc), dotted gayfeather (Lpu), common yellow oxalis (Ost), prairie junegrass (Kcr) and sideoats grama (Bcu) where adults were used.

Indiangrass (Snu) as compared to 19 other plants is shown in Table 4. A roll of film was accidentally dropped on a concrete floor causing it to unwind part of the film. Therefore, the degree of injury could not be graded for eight of the plants. However, based on average numbers of grasshoppers resting and feeding respectively as compared to indiangrass the following seem to be preferred: wholeleaf rosinweed (Sin) (11.2 vs. 0.2; 9.4 vs. 0.2); horseweed (Eca) (8.6 vs. 0.2; 1.2 vs. 0.2); baldwin ironweed (Vba) (3.6 vs. 0.2; 2.2 vs. 0.2); western yarrow (Ala) (3.4 vs. 0.0; 1.2 vs. 0.0); sagewort (Artem) (2.8 vs. 0.8; 2.0 vs. 0.4); and leadplant amorpha (Aca) (2.2 vs. 0.6; 1.0 vs. 0.4). Of the 11 plants which were graded, six were ranked with a higher degree of injury than indiangrass. The average numbers of grasshoppers resting and feeding respectively on these six preferred plants based on grading as compared to indiangrass were: aster (Aster) (10.3 vs. 0.2; 3.5 vs. 0.0); scurfpea (Pfl) (7.5 vs. 1.0; 2.0 vs. 0.2); scribner panicum (Psc) (4.2 vs. 3.4; 2.8 vs. 2.8); common ragweed (Ael) (2.8 vs. 2.0; 1.8 vs. 1.4); inland ceanothus (Cov) (2.6 vs. 0.8; 1.2 vs. 0.4); and western ragweed (Aps) (1.5 vs. 1.5; 0.7 vs. 0.5). Indiangrass was preferred over purple prairieclover (Ppu), prairie junegrass (Kcr), sideoats grama (Bcu), dotted gayfeather (Lpu), and little bluestem (Asc). In no case was a "D" grade assigned to any plant in Table 4; however, in the comparison of indiangrass vs. sideoats grama (Bcu), indiangrass is graded "C-", and footnoted indicating that one replicate was completely consumed. This replicate was graded "D" yet the average of three replicates remains a "C-". No feeding was observed at 60° F., however, four grasshoppers were feeding at 59° F. below which all feeding terminated.

Preferred resting sites were wholeleaf rosinweed (Sin), aster (Aster), and horseweed (Eca).

Data in Table 4 were concerned with 3rd and 4th instar nymphs except those on: common ragweed (Ael), and inland ceanothus (Cov), where 4th and 5th instar nymphs were used; and on little bluestem (Asc), prairie junegrass (Kcr), sideoats grama (Bcu), scribner panicum (Psc), and dotted gayfeather (Lpu) where adults were used.

Sideoats grama (Bcu) as compared to 16 other plants is shown in Table 5. Grading indicates that nine plants were preferred over sideoats grama. Two plants, aster (Aster) and common ragweed (Ael), were completely consumed in all three replicates (grade "D"). In four cases one of the three replicates was completely consumed as indicated by footnote [d]. These four cases were: purple prairieclover (Ppu), western ragweed (Aps), western yarrow (Ala), and scribner panicum (Psc). The average numbers of grasshoppers resting and feeding respectively on the nine preferred plants based on grading as compared to sideoats grama were: scribner panicum (Psc) (8.2 vs. 2.8; 5.4 vs. 2.2); aster (Aster) (7.8 vs. 1.2; 6.4 vs. 1.0); common ragweed (Ael) (7.4 vs. 1.6; 6.4 vs. 1.0); inland ceanothus (Cov) (6.2 vs. 1.4; 4.2 vs. 1.4); little bluestem (Asc) (4.2 vs. 4.4; 3.6 vs. 3.4); purple prairieclover (Ppu) (3.6 vs. 2.6; 1.4 vs. 0.8); baldwin ironweed (Vba) (2.8 vs. 1.2; 2.4 vs. 0.6); western ragweed (Aps) (2.6 vs. 1.6; 1.8 vs. 0.8); and western yarrow (Ala) (1.4 vs. 2.0; 1.4 vs. 1.8). Equal damage based on grading compared to sideoats grama was observed on leadplant amorpha (Aca), catclaw sensitivebriar (Sun), common yellow oxalis (Ost), prairie junegrass (Kcr), and dotted gayfeather (Lpu). Sideoats grama was preferred over falseboneset kuhnia (Keu), and sagewort (Artem).

In no case was a "D" grade assigned to sideoats grama. Preferred resting sites were scribner panicum (Psc), aster (Aster), leadplant amorpha (Aca), dotted gayfeather (Lpu) and common ragweed (Ael). No feeding was observed at 63° F.

Data in Table 5 were concerned with 4th and 5th instar nymphs except those on scribner panicum (Psc), little bluestem (Asc), prairie junegrass (Kcr), and dotted gayfeather (Lpu) where adults were used.

Prairie junegrass (Kcr) compared to 17 other plants is shown in Table 6. Grading indicates that 11 plants were preferred over prairie junegrass. All three replicates were completely consumed in two cases: common ragweed (Ael) and scurfpea (Pfl). Two plants, aster (Aster) and western yarrow (Ala) are graded "D+" and footnoted indicating that two of the three replicates were completely consumed. Leadplant amorpha (Aca) and baldwin ironweed (Vba) are graded "C-" and footnoted indicating that one replicate was completely consumed. The average numbers of grasshoppers resting and feeding respectively on the 11 preferred plants based on grading as compared to prairie junegrass were: aster (Aster) (10.2 vs. 0.4; 6.2 vs. 0.2); leadplant amorpha (Aca) (4.8 vs. 0.2; 3.0 vs. 0.2); western yarrow (Ala) (4.0 vs. 0.0; 2.0 vs. 0.0); dotted gayfeather (Lpu) (3.6 vs. 0.4; 0.4 vs. 0.0); scurfpea (Pfl) (3.6 vs. 0.4; 1.4 vs. 0.0); horseweed (Eca) (3.0 vs. 0.6; 1.4 vs. 0.2); baldwin ironweed (Vba) (2.8 vs. 0.4; 0.8 vs. 0.2); common ragweed (Ael) (2.2 vs. 0.4; 0.4 vs. 0.2); scribner panicum (Psc) (1.6 vs. 0.8; 0.0 vs. 0.0); western ragweed (Aps) (1.2 vs. 1.2; 0.8 vs. 0.4); and catclaw sensitivebriar (Sun) (0.2 vs. 1.0; 0.2 vs. 0.6). Equal damage based on grading compared to prairie junegrass was observed on falseboneset kuhnia (Keu) and purple prairieclover (Ppu). Prairie junegrass was preferred over sagewort (Artem), inland ceanothus (Cov), and wholeleaf rosinweed (Sin). In no case was a "D" grade assigned to prairie junegrass. Aster (Aster) and inland ceanothus (Cov) were the two most obvious preferred resting sites. Two grasshoppers were observed feeding at 56° F., however, only minor injury resulted. All other feeding in the 50° F. to 60° F. range terminated.

Data in Table 6 were concerned with 3rd and 4th instar nymphs except those on inland ceanothus (Cov), and wholeleaf rosinweed (Sin) where 4th and 5th instar nymphs were used; and on dotted gayfeather (Lpu), scribner panicum (Psc), and common yellow oxalis (Ost) where adults were used.

Little bluestem (Asc) as compared to 19 other plants is shown in Table 7. Grading indicates that nine plants were preferred over little bluestem. The average numbers of grasshoppers resting and feeding respectively on the nine preferred plants based on grading as compared to little bluestem were: western yarrow (Ala) (4.7 vs. 1.0; 3.7 vs. 0.5); baldwin ironweed (Vba) (4.2 vs. 1.2; 3.8 vs. 0.8); horseweed (Eca) (4.0 vs. 1.2; 2.6 vs. 0.8); aster (Aster) (3.6 vs. 1.2; 3.0 vs. 0.8); wholeleaf rosinweed (Sin) (3.5 vs. 0.5; 2.8 vs. 0.3); common ragweed (Ael) (2.2 vs. 0.7; 1.5 vs. 0.5); scribner panicum (Psc) (1.8 vs. 1.4; 0.4 vs. 0.2); leadplant amorpha (Aca) (1.2 vs. 0.6; 1.2 vs. 0.6); and sideoats grama (Bcu) (0.6 vs. 1.0; 0.0 vs. 0.2). Equal damage based on grading compared to little bluestem was observed on sagewort (Artem), scurfpea (Pfl), and common yellow oxalis (Ost). Little bluestem was preferred over falseboneset kuhnia (Keu), purple prairieclover (Ppu), western ragweed (Aps), catclaw sensitivebriar (Sun), prairie junegrass (Kcr), dotted gayfeather (Lpu), and inland ceanothus (Cov). In no case was a "D" grade assigned to any plant in Table 7; however, in the comparison of little bluestem (Asc) vs. horseweed (Eca), horseweed is graded "C-" and footnoted indicating that one replicate was completely consumed. This replicate was graded "D" yet the average of three replicates remains a "C-". Western yarrow (Ala), baldwin ironweed (Vba), and horseweed (Eca) were preferred resting sites. No feeding was observed in the 50° F. to 60° F. temperature range.

Data in Table 7 were concerned with 4th and 5th instar nymphs except those on sideoats grama (Bcu), prairie junegrass (Kcr), scribner panicum (Psc), dotted gayfeather (Lpu), and common yellow oxalis (Ost) where adults were used.

M. f. femurrubrum (DeGeer) has been considered a severe pest and of great economic importance for many years. Ball (1942) states that it is one of the most destructive grasshoppers of the United States and Canada. The importance of this species has been based on damage done to cultivated crops. Peairs and Davidson (1956) consider it as one of the five species which cause about 90 percent of the grasshopper damage to cultivated crops in the United States. Claassen (1915) states that in the summer of 1913 Melanoplus femurrubrum (DeGeer) did considerable damage in Kansas especially to alfalfa. Metcalf and Flint (1939) list it as very destructive in legume fields and common along roadsides.

The importance of this species as a rangeland pest is unknown. Blatchley (1920) stated that it occurred everywhere in bluegrass pastures and meadows, along roadsides and borders of cultivated fields, on city lawns and in open woodlands. In Kansas, Wilbur (1936) listed it as one of several species present in limited numbers doing damage to pasture grass, especially brome grass, in 1932. Wilbur and Fritz

(1940) reported this species to be more evenly distributed over the three pastures studied than were any of the other species. Hebard (1931) noted that M. f. femurrubrum (DeGeer) was a very abundant and generally weed-loving species which occurred over all of Kansas, being particularly injurious to alfalfa. In 1936 he listed this species as present in weedy cultivated areas throughout North Dakota. Knutson (1937) found it in a variety of habitats in northeastern Texas but stated that immatures and adults were in an alfalfa field in great numbers and had completely stripped off the leaves over a five acre area. Isley (1944) listed it as having forbivorous mandibles.

During the summer of 1961 this species was observed in large quantities in certain areas of the bluestem range, yet very little apparent damage to grasses resulted. It is believed that the cage results (Table 8) closely indicate actual food preferences in the field because (1) the grasshoppers appeared to behave normally in the cage while crawling, feeding and resting; and (2) the literature on this species has suggested a forb habitat. Observations and experiments under artificial holding and experimental conditions, such as in laboratories, insectaries or cages in the field, are generally accepted as the best substitute for biological studies when direct field studies are impossible. Such was the case during these studies because it was believed better data on preferences could be determined by limiting choice to two species of plants rather than multiple choice which would have been the case in field studies. Even then, a cage would have been necessary.

M. f. femurrubrum (DeGeer) probably is of more economic importance as a beneficial insect rather than a harmful one on rangeland. This is in contrast to the generally accepted assumption on field crops, viz., that it is one of the four major crop pests, particularly on alfalfa.

SUMMARY

The economic importance of grasshoppers is determined by food plants. Food preferences and relationships of grasshopper species and plant species in bluestem pastures are not well understood. Data in this study are the results of cage studies of Melanoplus femurrubrum femurrubrum (DeGeer) conducted during the summer growing season of 1961.

Twenty grasshoppers of a given species were placed in each cage. A spread of two consecutive instars was the maximum allowed in each cage. The grasshoppers were allowed the opportunity to feed for 48 hours on either or both of two plant species for a given time period. Each experiment was replicated three times. Counts were made at 7 a.m., 12 noon, 5 p.m., and in some cases 10 p.m. during the 48 hour feeding period, recording total number of grasshoppers (1) resting on the plants; and (2) feeding on plants. Photographs also were taken of the plants immediately after removal from the cages. Photographs were ranked according to intensity-of-feeding as compared with before-feeding pictures. A grade of A, B, C, and D was used: A = no feeding; B = trace to 1/2 of plant eaten; C = 1/2 plus eaten; D = eaten entirely. Species of grasses vs. grasses, and grasses vs. forbs, were evaluated. A total of nine perennial grasses, 14 perennial forbs, two annual forbs, and two woody plants were used in the cage studies. A total of 64 plant species was used in correlation studies.

Preferred most over big bluestem were: aster, horseweed, common ragweed and scurfpea. All four species were completely consumed in each of three replicates.

Preferred most over sand dropseed were: horseweed, aster, dotted gayfeather and wholeleaf rosinweed. Horseweed was completely consumed in each of three replicates.

Preferred most over switchgrass were: western yarrow, sagewort, horseweed and dotted gayfeather. Western yarrow was completely consumed in each of three replicates.

Preferred most over indiangrass were: wholeleaf rosinweed, horseweed, baldwin ironweed and western yarrow.

Preferred most over sideoats grama were: aster, common ragweed, purple prairieclover and western ragweed. Aster and common ragweed were completely consumed in each of three replicates.

Preferred most over prairie junegrass were: common ragweed, scurfpea, aster and western yarrow.

Preferred most over little bluestem were: western yarrow, baldwin ironweed, horseweed and aster.

Horseweed appeared in the four most preferred plants in each case except sideoats grama, in which case it was not evaluated.

The work reported on here is considered a first step in obtaining clues as to preferred plant species which might be used in interpreting the reason for associations which exist between grasshopper and plant species, particularly in the bluestem regions of Kansas.

M. f. femurrubrum (DeGeer) probably is of more economic importance as a beneficial insect rather than a harmful one on rangeland.

"KENDALL'S RANK CORRELATION COEFFICIENT"
KENDALL'S TAU

Coefficient is: $T = \frac{S}{1/2N(N-1)}$

N = Number of pastures in which you have observations.

$1/2N(N-1) = 36$ for 9 pastures

$1/2N(N-1) = 21$ for 7 pastures

$1/2 \times 9 \times 8 = 36$

$1/2 \times 7 \times 6 = 21$

S = (Number of concordances) - (Number of discordances)

Rank the observations (insects) from 1 to 9 and put opposite each insect rank the corresponding plant rank.

For example: *Hypochlora alba* vs. *Andropogon gerardi*

1957 - ordinary upland

Insect Rank	1	2	3	4	5	6	7	8	9	
Plant Rank	8	4	9	6	2	1	7	5	3	
Concordances	1	4	0	1	3	3	0	0	=	12
Discordances	7	3	6	4	1	0	2	1	=	24
										36

(Total Concordances) plus (Total Discordances) = 1/2N(N-1)

S = 12 minus 24 = -12

$$T = \frac{S}{1/2N(N-1)} = \frac{-12}{36} = -.33$$

Fig. 1. Statistical formula used to evaluate correlations between numbers of a grasshopper and a plant species.

PLATE I

Correlation between populations of *Melanoplus femurrubrum femurrubrum* (DeGeer) and each of 11 plant species.

PLATE I

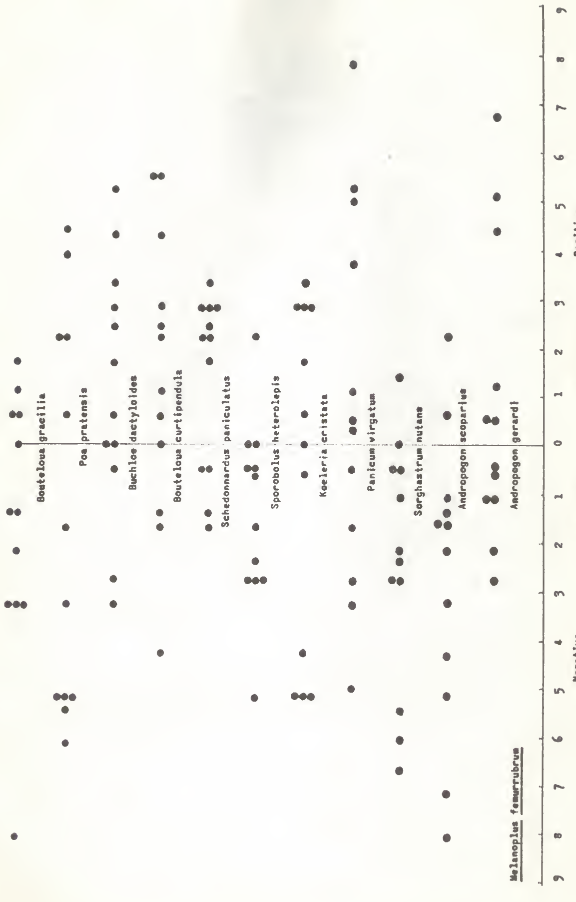
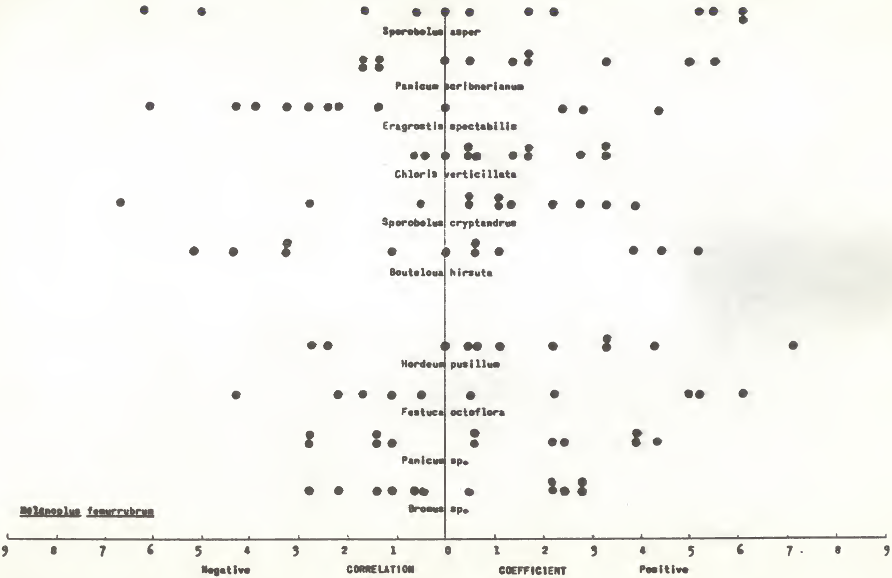

Melanoplus femurrubrus
Bouteloua gracilis
Poa pratensis
Buchloe dactyloides
Bouteloua curtipendula
Schedonnardus paniculatus
Sporobolus heterolepis
Koeleria cristata
Panicum virgatum
Sorghastrum nutans
Andropogon scoparius
Andropogon gerardi
9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9
Negative
CORRELATION
COEFFICIENT
Positive

PLATE II

Correlation between populations of *Melanoplus femurrubrum femurrubrum* (DeGeer) and each of 10 plant species.

PLATE II



Sporobolus asper
Panicum scribnerianum
Eragrostis spectabilis
Chloris verticillata
Sporobolus cryptandrus
Bouteloua hirsuta
Hordeum pusillum
Festuca octoflora
Panicum sp.
Bromus sp.
Melanoplus femurrubrum
9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9
Negative CORRELATION COEFFICIENT Positive

PLATE III

Correlation between populations of *Melanoplus femurrubrum femurrubrum* (DeGeer) and each of 11 plant species.

PLATE III

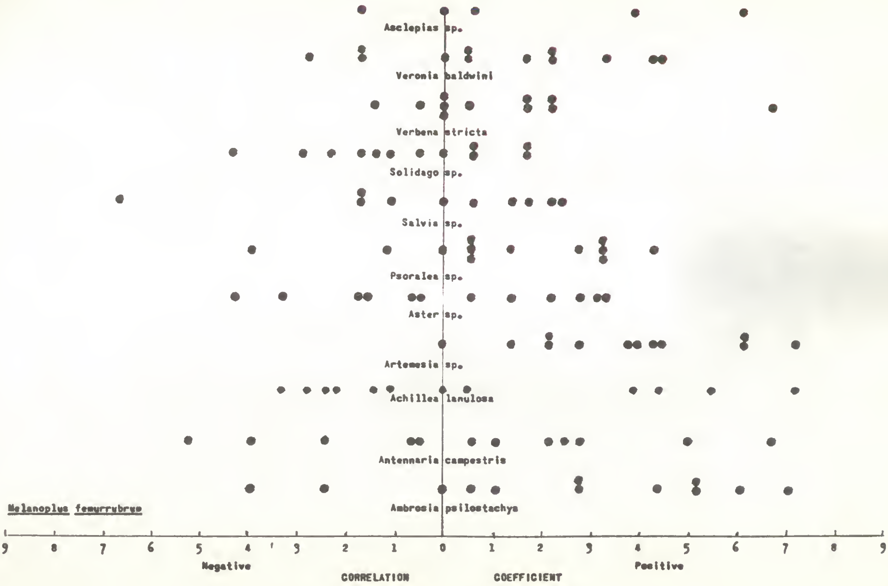

Asclepias sp.
Veronia baldwini
Verbena stricta
Solidago sp.
Salvia sp.
Psoralea sp.
Aster sp.
Artemesia sp.
Achillea lanulosa
Antennaria campestris
Ambrosia psilostachya
Melanoplus femurrubrum
9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9
Negative
Positive
CORRELATION COEFFICIENT

PLATE IV

Correlation between populations of *Melanoplus femurrubrum femurrubrum* (DeGeer) and each of 11 plant species.

PLATE IV

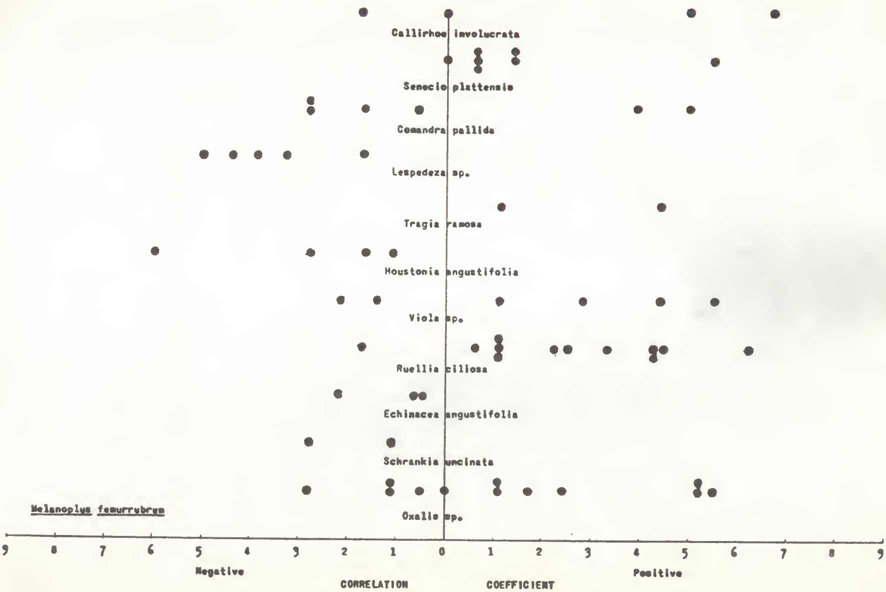

Callirhoe involucrata
Senecio plattensis
Comandra pallida
Lespedeza sp.
Tragia ramosa
Houstonia angustifolia
Viola sp.
Ruellia ciliosa
Echinacea angustifolia
Schrankia uncinata
Oxalis sp.
Melanoplus femurrubrum
9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9
Negative
Positive
CORRELATION COEFFICIENT

PLATE V

Correlation between populations of *Melanoplus femurrubrum femurrubrum* (DeGeer) and each of 10 plant species.

PLATE V

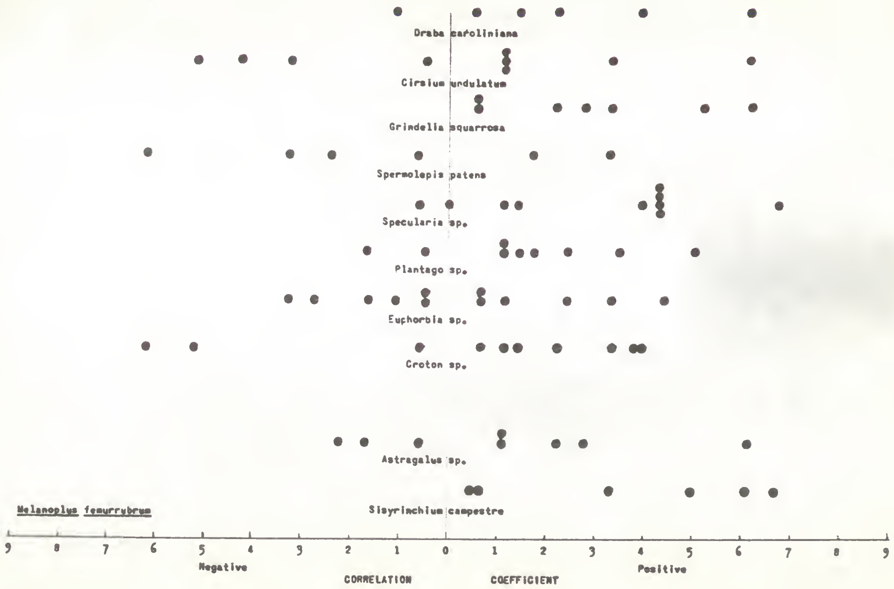

Draba caroliniana
Cirsium undulatum
Grindelia squarrosa
Spermolepis patens
Specularia sp.
Plantago sp.
Euphorbia sp.
Croton sp.
Astragalus sp.
Sisyrinchium campestre
Melanoplus femurrubrum
9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9
Negative
Positive
CORRELATION COEFFICIENT

PLATE VI

Correlation between populations of *Melanoplus femurrubrum femurrubrum* (DeGeer) and each of 11 plant species.

PLATE VI

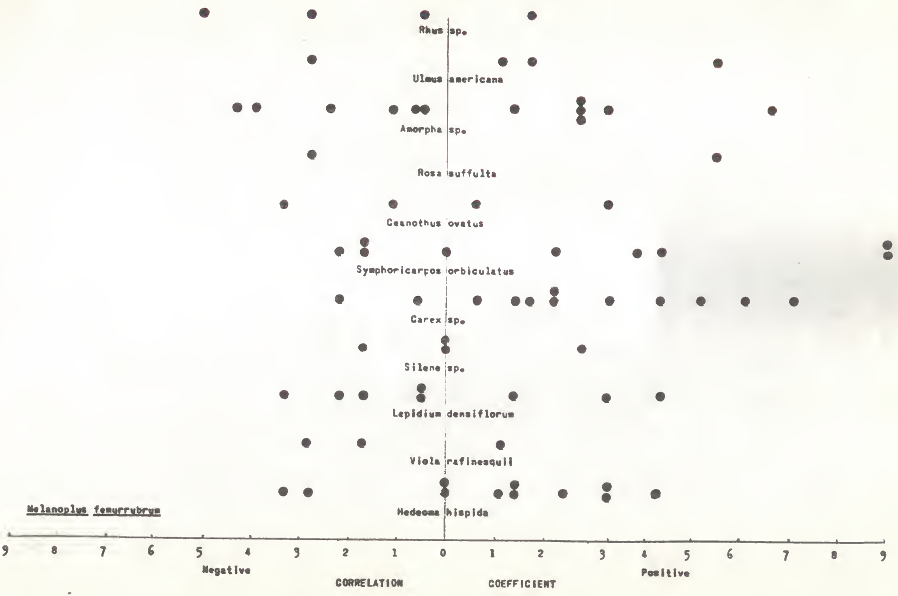

Rhus sp.
Ulmus americana
Amorpha sp.
Rosa suffulta
Ceanothus ovatus
Symphoricarpos orbiculatus
Carex sp.
Silene sp.
Lepidium densiflorum
Viola rafinesquii
Hedeoma hispida
Melanoplus femurrubrum
9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9
Negative
Positive
CORRELATION COEFFICIENT

Table 1. Number of <u>Melanoplus femurrubrum femurrubrum</u> (DeGeer) resting and feeding on <u>Andropogon gerardi</u> (Age) compared to various other species of plants at different times and temperatures during the day, and rating of feeding injury at 48 hours.

Time(a)	°F.(b)	(c)	Age	Ael(d)	Age	Eca	Age	Artem	Age	Rci	°F.	Age	Keu	Age	Aster	Age	Ppu	Age	Aps
5 pm		R	3	14	1	11	1	0	2	1		0	0	2	21	1	6	0	6
		F	1	10	1	9	1	0	2	1		0	0	1	14	1	5	0	6
10 pm		R	8	7	3	13	5	10	4	3		-	-	-	-	-	-	-	-
		F	0	0	0	2	1	4	0	1		-	-	-	-	-	-	-	-
7 am		R	3	2	0	8	5	4	2	2		0	0	0	14	0	10	1	7
		F	0	0	0	0	0	0	0	0		0	0	0	14	0	5	0	3
12 noon		R	1	5	1	9	1	11	0	1		1	0	1	2	0	1	0	5
		F	0	0	0	1	0	2	0	0		1	0	1	1	0	0	0	4
5 pm		R	0	7	3	14	2	8	2	8		1	3	1	10	0	2	0	4
		F	0	7	1	12	1	8	1	8		1	1	1	5	0	0	0	1
7 am		R	3	6	2	10	4	5	2	4		2	1	0	6	0	5	1	3
		F	0	2	0	1	0	3	0	0		1	0	0	6	0	0	0	1
12 noon		R	1	2	0	4	1	4	1	3		0	0	2	1	0	4	2	2
		F	0	1	0	3	0	3	0	2		0	0	1	1	0	3	2	2
5 pm		R	1	3	2	9	2	3	1	4		-	-	-	-	-	-	-	-
		F	0	2	2	9	2	3	0	4		-	-	-	-	-	-	-	-
7 am		R	0	5	1	2	1	4	1	3		-	-	-	-	-	-	-	-
		F	0	1	0	1	1	1	0	2		-	-	-	-	-	-	-	-
Average		R	2.2	5.7	1.4	8.9	2.4	5.4	1.7	3.2		0.7	0.7	1.0	9.0	0.2	4.7	0.7	4.5
		F	0.1	2.6	0.4	4.2	0.7	2.7	0.3	2.0		0.5	0.2	0.7	5.2	0.2	2.2	0.3	2.8
		IF(e)	B-	D	A	D	A	B	B	B		B	A	B+	D	A-	B	A-	B

Table 1. (cont.)

Time	°F.		Age	Pfl	Age	Sun	Age	Sin	Age	Vba	°F.	Age	Aca	Age	Ala	Age	Cov
5 pm		R	0	6	2	3	0	2	0	0		0	4	0	11	7	3
		F	0	2	2	1	0	2	0	0		0	0	0	2	3	1
7 am		R	0	2	0	2	1	3	0	0		0	2	0	6	6	3
		F	0	2	0	1	1	3	0	0		0	0	0	0	5	2
12 noon		R	0	0	1	1	0	13	0	0		1	5	2	5	0	0
		F	0	0	1	1	0	10	0	0		0	1	0	3	0	0
5 pm		R	1	5	2	0	1	13	1	3		0	4	0	4	1	2
		F	0	3	0	0	0	5	0	0		0	2	0	4	1	1
7 am		R	0	5	0	1	0	6	2	1		0	2	0	6	2	8
		F	0	1	0	1	0	4	2	0		0	1	0	2	2	3
Average		R	0.2	3.6	1.0	1.4	0.4	7.4	0.6	0.8		0.2	3.4	0.4	6.4	3.2	3.2
		F	0	1.6	0.6	0.8	0.2	4.8	0.4	0		0	0.8	0	2.2	2.2	1.4
		IF	A	D	B	B	A-	B	B	B		A-	B	A	C+	C+	B

			Age	Snu	Age	Kcr	Age	Asc	Age	Bcu		Age	Scr	Age	Psc	Age	Pvi	Age	Lpu
5 pm	78	R	8	1	12	3	12	4	4	3	78	4	5	6	10	6	1	3	3
		F	8	1	12	2	11	4	3	3		0	4	2	8	3	0	2	3
7 am	69	R	4	0	4	2	6	1	7	2	72	2	3	5	3	6	4	4	7
		F	2	0	4	2	6	1	5	1		2	2	1	2	1	2	2	3
12 noon	80	R	2	1	1	1	3	0	3	1	84	2	1	0	1	1	3	1	2
		F	1	0	1	1	3	0	3	1		1	1	0	0	0	1	0	2
5 pm	88	R	0	2	2	1	4	0	0	1	89	3	3	3	3	2	2	1	2
		F	0	2	2	1	4	0	0	1		1	1	2	1	1	1	1	1
7 am	73	R	1	1	2	0	1	0	1	0	75	5	2	0	2	2	2	3	6
		F	0	0	0	0	0	0	0	0		1	1	0	1	0	1	1	3

Table 1. (concl.)

Time	°F.		Age	Snu	Age	Kcr	Age	Asc	Age	Bcu	°F.	Age	Scr	Age	Psc	Age	Pvi	Age	Lpu
Average		R	3.0	1.0	4.2	1.4	5.2	1.0	3.0	1.4		3.2	2.8	2.8	3.8	3.4	2.4	2.4	4.0
		F	2.2	0.6	3.8	1.2	4.8	1.0	2.2	1.2		1.0	1.8	1.0	2.4	1.0	1.0	1.2	2.4
		IF	B+	B+	C+	A-	B-	B	B	A		B	B-	B	B	B	B	B	B

(a) Subsequent studies limited to 48 hours.
(b) Temperatures recorded in subsequent studies.
(c) R = number of grasshoppers resting on plants (total of 3 replicates).
F = number feeding (total of 3 replicates).
(d) Age - Andropogon gerardi; Ael - Ambrosia elatior; Eca - Erigeron canadensis; Artem - Artemesia spp.; Rci - Ruellia ciliosa; Keu - Kuhnia eupatoroides; Aster - Aster spp.; Ppu - Petalostemum purpureum; Aps - Ambrosia psilostachya; Pfl - Psoralea floribunda; Sun - Schrankia uncinata; Sin - Silphium integrifolium; Vba - Vernonia baldwini; Aca - Amorpha canescens; Ala - Achillea lanulosa; Cov - Ceanothus ovatus; Snu - Sorghastrum nutans; Kcr - Koeleria cristata; Asc - Andropogon scoparius; Bcu - Bouteloua curtipendula; Scr - Sporobolus cryptandrus; Psc - Panicum scribnerianum; Pvi - Panicum virgatum; Lpu - Liatris punctata.
(e) IF = intensity of feeding (average of 3 replicates). A = no feeding; B = trace to 1/2 of plant eaten; C = 1/2 plus; D = eaten entirely.

Table 2. Number of Melanoplus femurrubrum femurrubrum (DeGeer) resting and feeding on Sporobolus cryptandrus (Scr) compared to various other species of plants at different times and temperatures during the day, and rating of feeding injury at 48 hours.

Time	°F.(a)	(b)	Scr	Artem(c)	Scr	Cov	Scr	Keu	Scr	Eca	°F.	Scr	Aps	Scr	Aster	Scr	Ppu	Scr	Pfl
5 pm		R	2	6	6	12	2	5	3	10		3	13	6	21	7	2	1	1
		F	1	3	3	3	1	0	2	4		2	3	5	11	5	2	1	1
7 am		R	0	2	3	10	3	0	3	7		0	3	0	10	1	2	0	6
		F	0	0	2	0	1	0	0	3		0	0	0	3	0	0	0	1
12 noon		R	0	5	2	4	1	0	2	8		4	3	1	9	1	2	2	3
		F	0	0	0	2	1	0	1	5		1	2	0	4	0	1	2	0
5 pm		R	0	1	2	8	1	0	1	8		1	1	1	8	1	3	0	1
		F	0	1	2	3	0	0	0	2		1	1	1	7	0	3	0	1
7 am		R	0	0	1	2	0	0	0	1		1	2	1	4	0	0	2	1
		F	0	0	1	6	0	0	0	0		1	1	1	3	0	0	1	1
12 noon		R	0	2	1	3	0	0	1	1		-	-	-	-	-	-	-	-
		F	0	2	0	0	0	0	0	0		-	-	-	-	-	-	-	-
Average		R	0.3	2.7	2.5	6.5	1.2	0.8	1.7	5.8		1.8	4.4	1.8	10.4	2.0	1.8	1.0	2.4
		F	0.2	1.0	1.3	2.3	0.5	0	0.5	2.3		1.0	1.4	1.4	5.6	1.0	1.2	0.8	0.8
		IF(d)	B	B	B-	B	B	A-	B+	D		B	C+	A-	C	B-	A-	B	C

Time			Scr	Vba	Scr	Sun	Scr	Aca	Scr	Sin		Scr	Ael	Scr	Snu	Scr	Asc	Scr	Ost
5 pm	99	R	1	2	2	2	1	7	0	7	66	6	1	1	2	1	1	3	0
		F	1	2	2	1	1	1	0	5		1	0	1	1	1	0	3	0
7 am	85	R	0	5	1	2	1	0	0	7	54	2	0	2	3	0	0	1	1
		F	0	0	1	2	1	0	0	2		1	0	0	0	0	0	0	0
12 noon	90	R	0	2	2	1	0	2	2	7	64	1	1	2	6	3	1	1	1
		F	0	2	2	1	0	0	2	5		1	1	2	4	3	1	1	1

Table 2. (cont.)

Time	°F.	(b)	Scr	Vba	Scr	Sun	Scr	Aca	Scr	Sin	°F.	Scr	Ael	Scr	Snu	Scr	Asc	Scr	Ost
5 pm	84	R	3	4	3	1	2	1	1	8	72	5	3	1	2	1	1	3	1
		F	2	2	1	1	1	1	1	5		3	3	0	0	0	1	0	0
7 am	79	R	1	5	2	1	0	0	0	7	59	3	2	2	1	3	1	2	2
		F	1	0	1	1	0	0	0	0		1	1	1	0	3	0	2	1
12 noon	90	R	1	1	0	0	0	0	0	5	-	-	-	-	-	-	-	-	-
		F	1	1	0	0	0	0	0	4		-	-	-	-	-	-	-	-
Average		R	1.0	3.2	1.7	1.2	0.7	0.2	0.5	6.8		3.4	1.4	1.6	2.8	1.6	0.8	2.0	1.0
		F	0.8	1.2	1.2	1.0	0.5	0.3	0.5	3.5		1.4	1.0	0.8	1.0	1.4	0.4	1.2	0.4
		IF	B	B	B	B+	C+	B	B	B-		B-	C	B	B-	C+	B	C	B

Time	°F.	(b)	Scr	Lpu	Scr	Psc	Scr	Kcr	Scr	Bcu
5 pm	61	R	3	14	6	1	1	1	2	0
		F	2	14	5	0	0	0	2	0
7 am	50	R	1	8	3	0	1	1	3	0
		F	0	0	0	0	0	0	0	0
12 noon	55	R	2	7	1	1	1	2	1	0
		F	1	0	0	0	0	0	0	0
5 pm	62	R	0	11	2	4	3	1	3	2
		F	0	4	1	3	0	0	3	1
7 am	48	R	1	5	1	1	2	1	4	1
		F	0	0	0	0	0	0	0	0
Average		R	1.4	9.0	2.6	1.4	1.6	1.2	2.6	0.6
		F	0.6	3.6	1.2	0.6	0	0	1.0	0.2
		IF	B+	B	B	B+	B	B+	B	A-

Table 2. (concl.)

(a) Temperatures recorded in subsequent studies.

(b) R = number of grasshoppers resting on plant (total of 3 replicates).
F = number feeding (total of 3 replicates).

(c) Scr - *Sporobolus cryptandrus*; Artem - *Artemesia* spp.; Cov - *Ceanothus ovatus*; Keu - *Kuhnia eupatoroides*; Eca - *Erigeron canadensis*; Aps - *Ambrosia psilostachya*; Aster - *Aster* spp.; Ppu - *Petalostemum purpureum*; Pfl - *Psoralea floribunda*; Vba - *Vernonia baldwini*; Sun - *Schrankia uncinata*; Aca - *Amorpha canescens*; Sin - *Silphium integrifolium*; Ael - *Ambrosia elatior*; Snu - *Sorghastrum nutans*; Asc - *Andropogon scoparius*; Ost - *Oxalis stricta*; Lpu - *Liatrus punctata*; Psc - *Panicum scribnerianum*; Kcr - *Koeleria cristata*; Bcu - *Bouteloua curtipendula*.

(d) IF = intensity of feeding (average of 3 replicates). A = no feeding; B = trace to 1/2 of plant eaten; C = 1/2 plus; D = eaten entirely.

Table 3. Number of Melanoplus femurrubrum femurrubrum (DeGeer) resting and feeding on Panicum virgatum (Pvi) compared to various other species of plants at different times and temperatures during the day, and rating of feeding injury at 48 hours.

Time	°F.	(a)	Pvi	Aps[b]	Pvi	Pfl	Pvi	Aster	Pvi	Ppu	°F.	Pvi	Keu	Pvi	Artem	Pvi	Ala	Pvi	Eca
5 pm	82	R	4	8	3	13	2	6	2	1	-	2	1	2	13	1	12	0	11
		F	1	3	2	8	0	0	1	1		0	0	0	7	0	2	0	0
7 am	78	R	2	8	2	7	0	5	2	2	76	2	0	2	5	2	5	0	17
		F	0	1	0	2	0	0	0	0		1	0	1	3	0	1	0	0
12 noon	82	R	0	3	1	1	1	5	1	9	88	4	0	0	2	0	1	1	1
		F	0	1	0	0	1	2	1	3		1	0	0	0	0	0	0	0
5 pm	85	R	1	6	1	2	3	7	4	2	90	2	0	1	0	1	2	0	4
		F	1	4	0	1	0	2	3	0		0	0	1	0	0	1	0	2
7 am	78	R	1	3	0	1	4	1	1	1	78	0	0	1	2	2	1	1	2
		F	1	0	0	1	1	0	0	0		0	0	0	2	1	0	0	2
12 noon	86	R	1	2	0	0	1	3	2	0	-	-	-	-	-	-	-	-	-
		F	1	0	0	0	0	2	1	0		-	-	-	-	-	-	-	-
Average		R	1.5	5.0	1.2	4.0	1.8	4.5	2.0	2.5		2.0	0.2	1.2	4.4	1.2	4.2	0.4	7.0
		F	0.7	1.5	0.3	2.0	0.3	1.0	1.0	0.7		0.4	0	0.4	2.4	0.2	0.8	0	0.8
		IF[c]	B	B-	B+	C	A-	C	B	A		B	A-	-	-	B	D	-	-
			Pvi	Vba	Pvi	Sun	Pvi	Aca	Pvi	Sin		Pvi	Ael	Pvi	Cov				
5 pm	99	R	5	6	1	0	1	2	0	6	81	1	6	3	2				
		F	3	4	1	0	0	1	0	4		1	6	3	2				
7 am	85	R	2	2	3	0	1	2	2	7	73	5	2	7	1				
		F	1	0	1	0	0	0	0	0		2	1	2	0				
12 noon	90	R	1	1	1	0	0	2	0	6	82	1	5	4	2				
		F	1	1	1	0	0	2	0	4		0	1	1	2				
5 pm	84	R	7	1	4	0	2	1	4	14	85	0	8	1	3				
		F	5	0	3	0	2	1	3	8		0	3	1	0				

Table 3. (cont.)

Time	°F.	(a)	Pvi	Vba	Pvi	Sun	Pvi	Aca	Pvi	Sin	°F.	Pvi	Ael	Pvi	Cov				
7 am	79	R	0	2	2	0	1	0	4	8	78	1	3	0	11				
		F	0	0	0	0	0	0	0	0		0	2	0	0				
12 noon	90	R	4	1	5	0	0	0	0	1	-	-	-	-	-				
		F	1	0	4	0	0	0	0	1		-	-	-	-				
Average		R	3.2	2.2	2.7	0	0.8	1.2	1.7	7.0		1.6	4.8	3.0	3.8				
		F	1.8	0.8	1.7	0	0.3	0.7	0.5	2.8		0.6	2.6	1.4	0.8				
		IF	B	B	B	B+	B+	B-(d)	A-	C+		A-	B	B	B				
			Pvi	Lpu	Pvi	Ost	Pvi	Kcr	Pvi	Bcu		Pvi	Asc	Pvi	Scr	Pvi	Snu	Pvi	Psc
5 pm	76	R	5	15	4	2	8	2	11	0	89	12	11	6	3	13	6	8	21
		F	2	9	0	0	3	1	2	0		12	9	6	3	13	6	7	18
7 am	68	R	2	15	5	4	6	2	9	1	74	2	1	4	0	4	3	2	5
		F	0	0	1	2	0	0	0	0		0	1	3	0	3	2	0	2
12 noon	71	R	2	4	2	3	5	3	2	2	86	0	0	1	2	2	0	3	0
		F	2	1	0	1	3	1	0	1		0	0	0	1	2	0	3	0
5 pm	72	R	4	16	4	0	8	2	7	0	84	2	2	7	2	3	2	5	1
		F	1	9	1	0	2	0	4	0		1	1	5	1	1	0	2	1
7 am	54	R	1	10	4	0	2	0	2	1	69	3	0	3	2	2	1	3	1
		F	0	1	1	0	0	0	1	0		2	0	2	0	2	0	2	0
Average		R	2.8	12.0	3.8	1.8	5.8	1.8	6.2	0.8		3.8	2.8	4.2	1.8	4.8	2.4	4.2	5.6
		F	1.0	4.0	0.6	0.6	1.6	0.4	1.4	0.2		3.0	2.2	3.2	1.0	4.2	1.6	2.8	4.2
		IF	B	B-	B-	B	C+	B	C	A		C+	C(d)	B	B-	C+	B	C+	C+

Table 3. (concl.)

(a) R = number of grasshoppers resting on plants (total of 3 replicates).
F = number feeding (total of 3 replicates).

(b) Pvi - *Panicum virgatum*; Aps - *Ambrosia psilostachya*; Pfl - *Psoralea floribunda*; Aster - *Aster* spp.; Ppu - *Petalostemum purpureum*; Keu - *Kuhnia eupatoroides*; Artem - *Artemesia* spp.; Ala - *Achillea lanulosa*; Eca - *Erigeron canadensis*; Vba - *Vernonia baldwini*; Sun - *Schrankia uncinata*; Aca - *Amorpha canescens*; Sin - *Silphium integrifolium*; Ael - *Ambrosia elatior*; Cov - *Ceanothus ovatus*; Lpu - *Liatrus punctata*; Ost - *Oxalis stricta*; Kcr - *Koeleria cristata*; Bcu - *Bouteloua curtipendula*; Asc - *Andropogon scoparius*; Scr - *Sporobolus cryptandrus*; Snu - *Sorghastrum nutans*; Psc - *Panicum scribnerianum*.

(c) IF = intensity of feeding (average of 3 replicates). A = no feeding; B = trace to 1/2 of plant eaten; C = 1/2 plus; D = eaten entirely.

(d) One or more plants completely consumed in one or two replicates; letter grade indicates average degree of injury in 3 replicates.

Table 4. Number of Melanoplus femurrubrum femurrubrum (DeGeer) resting and feeding on Sorghastrum nutans (Snu) compared to various other species of plants at different times and temperatures during the day, and rating of feeding injury at 48 hours.

Time	°F.	(a)	Snu	Vba(b)	Snu	Aca	Snu	Sun	Snu	Sin	°F.	Snu	Aps	Snu	Pfl	Snu	Aster	Snu	Ppu
5 pm	93	R	0	2	2	2	1	1	1	12	82	2	3	1	12	0	12	3	1
		F	0	2	2	0	1	1	1	10		1	2	0	1	0	3	0	0
7 am	73	R	0	4	0	2	0	2	0	10	78	1	1	1	15	0	14	0	2
		F	0	2	0	1	0	0	0	7		0	0	0	3	0	2	0	1
12 noon	80	R	0	6	0	2	0	0	0	13	82	0	1	3	6	0	11	1	0
		F	0	3	0	2	0	0	0	12		0	0	0	3	0	2	0	0
5 pm	88	R	1	6	0	3	1	2	0	13	85	6	1	0	3	0	15	4	3
		F	1	4	0	1	1	0	0	13		2	0	0	3	0	9	2	0
7 am	-	R	0	0	1	2	0	1	0	8	78	0	3	1	4	1	10	4	4
		F	0	0	0	1	0	0	0	5		0	2	1	0	0	5	0	3
12 noon	-	R	-	-	-	-	-	-	-	-	86	0	0	0	3	0	0	3	0
		F	-	-	-	-	-	-	-	-		0	0	0	2	0	0	1	0
Average		R	0.2	3.6	0.6	2.2	0.4	1.2	0.2	11.2		1.5	1.5	1.0	7.5	0.2	10.3	2.5	1.7
		F	0.2	2.2	0.4	1.0	0.4	0.2	0.2	9.4		0.5	0.7	0.2	2.0	0	3.5	0.5	0.7
		IF(c)	-	-	-	-	-	-	-	-		B	B-	B	C	A-	C	B	A
			Snu	Keu	Snu	Artem	Snu	Ala	Snu	Eca		Snu	Kcr	Snu	Bcu	Snu	Psc	Snu	Lpu
5 pm	-	R	0	0	1	7	0	5	0	22	80	6	11	5	2	10	10	9	1
		F	0	0	1	5	0	1	0	4		5	10	5	1	10	9	9	1
7 am	76	R	0	0	1	4	0	7	0	14	60	1	1	1	1	1	2	0	2
		F	0	0	0	2	0	0	0	1		0	0	0	0	0	0	0	0
12 noon	88	R	0	0	0	1	0	2	1	5	76	3	1	0	0	0	3	0	1
		F	0	0	0	1	0	2	1	1		2	0	0	0	0	1	0	0
5 pm	90	R	2	1	2	1	0	2	0	2	76	4	0	3	0	4	5	4	5
		F	0	0	1	1	0	2	0	0		4	0	3	0	4	4	4	4

Table 4. (cont.)

Time	°F.	(a)	Snu	Keu	Snu	Artem	Snu	Ala	Snu	Eca	°F.	Snu	Kcr	Snu	Bcu	Snu	Psc	Snu	Lpu
7 am	78	R	0	0	0	1	0	1	0	0	62	2	2	1	1	2	1	2	4
		F	0	0	0	1	0	1	0	0		0	0	0	0	0	0	2	1
Average		R	0.4	0.2	0.8	2.8	0	3.4	0.2	8.6		3.2	3.0	2.0	0.8	3.4	4.2	3.0	2.6
		F	0	0	0.4	2.0	0	1.2	0.2	1.2		2.2	2.0	1.6	0.2	2.8	2.8	3.0	1.2
		IF	-	-	-	-	-	-	-	-		C	A-	C-(d)	B+	C+	C	C+	B

Time	°F.	(a)	Snu	Ael	Snu	Cov	°F.	Snu	Asc
5 pm	81	R	1	6	2	2	66	3	0
		F	1	5	1	2		3	0
7 am	73	R	1	2	1	1	54	3	0
		F	1	1	0	0		0	0
12 noon	82	R	4	1	1	1	64	3	1
		F	2	0	1	0		1	0
5 pm	85	R	4	3	0	7	72	2	1
		F	3	1	0	2		1	0
7 am	78	R	0	2	0	2	59	4	2
		F	0	2	0	2		3	1
Average		R	2.0	2.8	0.8	2.6		3.0	0.8
		F	1.4	1.8	0.4	1.2		1.6	0.2
		IF	B+	C	B	B-		C	B

(a) R = number of grasshoppers resting on plants (total of 3 replicates).
F = number feeding (total of 3 replicates).

Table 4. (concl.)

(b) Snu - Sorghastrum nutans; Vba - Vernonia baldwini; Aca - Amorpha canescens; Sun - Schrankia uncinata; Sin - Silphium integrifolium; Aps - Ambrosia psilostachya; Pfl - Psoralea floribunda; Aster - Aster spp.; Ppu - Petalostemum purpureum; Keu - Kuhnia eupatoroides; Artem - Artemesia spp.; Ala - Achillea lanulosa; Eca - Erigeron canadensis; Lpu - Liatrus punctata; Ael - Ambrosia elatior; Cov - Ceanothus ovatus; Asc - Andropogon scoparius.

(c) IF = intensity of feeding (average of 3 replicates). A = no feeding; B = trace to 1/2 of plant eaten; C = 1/2 plus; D = eaten entirely.

(d) One or more plants completely consumed in one or two replicates; letter grade indicates average degree of injury in 3 replicates.

Table 5. Number of Melanoplus femurrubrum femurrubrum (DeGeer) resting and feeding on Bouteloua curtipendula (Bcu) compared to various other species of plants at different times and temperatures during the day, and rating of feeding injury at 48 hours.

Time	°F.	(a)	Bcu	Keu[b]	Bcu	Aca	Bcu	Ppu	Bcu	Aps	°F.	Bcu	Sun	Bcu	Aster	Bcu	Ala	Bcu	Cov
5 pm	93	R	1	0	0	13	2	4	1	1	96	7	2	4	20	6	2	6	3
		F	1	0	0	11	2	2	1	1		7	0	4	12	6	2	6	2
7 am	74	R	2	1	2	8	2	3	1	2	74	1	1	1	1	0	1	1	7
		F	2	0	1	6	0	1	0	1		1	1	0	0	0	1	1	3
12 noon	88	R	1	1	3	7	2	4	1	5	84	0	1	1	6	1	1	0	4
		F	1	0	1	7	1	0	0	3		0	1	1	6	1	1	0	4
5 pm	90	R	3	1	3	9	3	7	5	4	90	3	1	0	6	1	3	0	11
		F	2	0	2	6	0	4	3	4		3	1	0	6	0	3	0	6
7 am	74	R	1	1	1	1	4	0	0	1	76	2	2	0	6	2	0	0	6
		F	1	0	0	0	1	0	0	0		1	2	0	3	2	0	0	6
Average		R	1.6	0.8	1.8	7.6	2.6	3.6	1.6	2.6		2.6	1.4	1.2	7.8	2.0	1.4	1.4	6.2
		F	1.4	0	0.8	6.0	0.8	1.4	0.8	1.8		2.4	1.0	1.0	6.4	1.8	1.4	1.4	4.2
		IF[c]	C	B	C	C	B-	C-[d]	B-	C[d]		B	B	C	D	B	C-[d]	B-	C
			Bcu	Vba	Bcu	Ael	Bcu	Artem	Bcu	Ost		Bcu	Psc	Bcu	Asc	Bcu	Kcr	Bcu	Lpu
5 pm	90	R	2	6	3	21	3	4	2	10	76	8	21	14	15	8	6	5	18
		F	2	6	2	17	2	4	1	10		8	21	13	14	8	5	3	14
7 am	74	R	0	4	3	6	1	3	1	5	63	1	10	2	2	0	0	2	4
		F	0	2	1	6	0	2	0	2		0	0	0	0	0	0	0	0
12 noon	86	R	2	0	1	0	0	2	1	1	66	3	4	3	4	3	5	3	1
		F	0	0	1	0	0	2	1	1		3	4	3	4	1	3	2	1
5 pm	88	R	0	4	1	4	0	3	2	1	68	2	5	0	0	3	2	2	8
		F	0	4	1	3	0	3	2	1		0	2	0	0	1	0	0	0
7 am	76	R	2	0	0	6	3	0	0	3	63	0	1	3	0	2	1	0	6
		F	1	0	0	6	3	0	0	3		0	0	1	0	1	1	0	1

Table 5. (concl.)

Time	°F.	(a)	Bcu	Vba	Bcu	Ael	Bcu	Artem	Bcu	Ost	°F.	Bcu	Psc	Bcu	Asc	Bcu	Kcr	Bcu	Lpu
Average		R	1.2	2.8	1.6	7.4	1.4	2.4	1.2	4.0		2.8	8.2	4.4	4.2	3.2	2.8	2.4	7.4
		F	0.6	2.4	1.0	6.4	1.0	2.2	0.8	3.4		2.2	5.4	3.4	3.6	2.2	1.8	1.0	3.2
		IF	B+	C+	B+	D	B-	B	C+	C+		B+	C-(d)	B	C+	B	B	B	B

(a) R = number of grasshoppers resting on plants (total of 3 replicates).
F = number feeding (total of 3 replicates).

(b) Bcu - _Bouteloua curtipendula_; Keu - _Kuhnia eupatoroides_; Aca - _Amorpha canescens_; Ppu - _Petalostemum purpureum_; Aps - _Ambrosia psilotachya_; Sun - _Schrankia uncinata_; Aster - _Aster_ spp.; Ala - _Achillea lanulosa_; Cov - _Ceanothus ovatus_; Vba - _Vernonia baldwini_; Ael - _Ambrosia elatior_; Artem - _Artemesia_ spp.; Ost - _Oxalis stricta_; Psc - _Panicum scribnerianum_; Asc - _Andropogon scoparius_; Kcr - _Koeleria cristata_; Lpu - _Liatrus punctata_.

(c) IF = intensity of feeding (average of 3 replicates). A = no feeding; B = trace to 1/2 of plant eaten; C = 1/2 plus; D = eaten entirely.

(d) One or more plants completely consumed in one or two replicates; letter grades indicate average degree of injury in 3 replicates.

Table 6. Number of <u>Melanoplus femurrubrum femurrubrum</u> (DeGeer) resting and feeding on <u>Koeleria cristata</u> (Kcr) compared to various other species of plants at different times and temperatures during the day, and rating of feeding injury at 48 hours.

Time	°F.	(a)	Kcr	Artm[b]	Kcr	Aca	Kcr	Vba	Kcr	Ael	°F.	Kcr	Pfl	Kcr	Keu	Kcr	Ppu	Kcr	Aps
5 pm	-	R	0	7	0	1	0	2	0	2	89	1	3	0	1	1	0	3	0
		F	0	2	0	1	0	1	0	0		0	1	0	0	0	0	2	0
7 am	72	R	0	1	0	3	0	6	0	4	78	0	4	1	2	0	2	1	2
		F	0	1	0	3	0	0	0	0		0	2	1	1	0	1	0	0
12 noon	88	R	3	0	0	11	1	3	1	1	90	0	2	0	0	0	1	0	0
		F	2	0	0	11	1	3	1	1		0	1	0	0	0	0	0	0
5 pm	92	R	2	3	1	5	0	2	0	3	100	0	7	0	0	0	3	1	2
		F	0	1	1	1	0	0	0	0		0	2	0	0	0	0	0	2
7 am	80	R	2	1	0	4	1	1	1	1	76	0	1	0	0	0	0	0	2
		F	0	0	0	1	0	0	0	1		0	1	0	0	0	0	0	2
Average		R	1.4	2.4	0.2	4.8	0.4	2.8	0.4	2.2		0.4	3.6	0.4	0.6	0.2	1.4	1.2	1.2
		F	0.4	0.8	0.2	3.0	0.2	0.8	0.2	0.4		0	1.4	0.2	0.2	0	0.2	0.4	0.8
		IF[c]	C+	B	B	C-[d]	B-	C-[d]	B-	D		B	D	B+	B+	B-	B-	B-	C+
			Kcr	Sun	Kcr	Eca	Kcr	Aster	Kcr	Ala		Kcr	Lpu	Kcr	Psc	Kcr	Ost		
5 pm	85	R	1	0	0	2	0	14	0	12	55	1	2	0	2	0	0		
		F	1	0	0	2	0	8	0	2		0	0	0	0	0	0		
7 am	73	R	2	0	1	5	1	17	0	3	53	1	6	0	1	2	0		
		F	0	0	0	2	0	12	0	3		0	0	0	0	0	0		
12 noon	81	R	0	1	0	2	1	12	0	5	58	0	0	0	0	0	0		
		F	0	1	0	2	1	7	0	5		0	0	0	0	0	0		
5 pm	88	R	1	0	0	1	0	3	0	0	56	0	4	2	3	3	0		
		F	1	0	0	1	0	3	0	0		0	2	0	0	0	0		
7 am	73	R	1	0	2	5	0	5	0	0	50	0	3	1	0	2	0		
		F	1	0	1	2	0	1	0	0		0	0	0	0	0	0		

Table 6. (cont.)

Time	°F.	(a)	Kcr	Sun	Kcr	Eca	Kcr	Aster	Kcr	Ala	°F.	Kcr	Lpu	Kcr	Psc	Kcr	Ost
Average		R	1.0	0.2	0.6	3.0	0.4	10.2	0	4.0		0.4	3.6	0.8	1.6	1.8	0
		F	0.6	0.2	0.2	1.4	0.2	6.2	0	2.0		0	0.4	0	0	0	0
		IF	B	B-	B+	C	A-	D+(d)	B	D+(d)		A	B	A	B	-	-

Time	°F.	(a)	Kcr	Cov	Kcr	Sin
5 pm	78	R	11	3	9	4
		F	9	0	7	0
7 am	68	R	2	15	3	9
		F	1	3	1	6
12 noon	78	R	2	6	1	10
		F	1	4	0	7
5 pm	78	R	0	2	1	0
		F	0	2	0	0
7 am	67	R	2	13	0	4
		F	1	6	0	3
12 noon	72	R	9	1	2	2
		F	7	0	2	0
Average		R	4.3	6.7	2.7	4.8
		F	3.2	2.5	1.7	2.7
		IF	C+	B	B	B+

(a) R = number of grasshoppers resting on plants (total of 3 replicates).
F = number feeding (total of 3 replicates).

Table 6. (concl.)

(b) Kcr - *Koeleria cristata*; Artem - *Artemesia* spp.; Aca - *Amorpha canescens*; Vba - *Vernonia baldwini*; Ael - *Ambrosia elatior*; Pfl - *Psoralea floribunda*; Keu - *Kuhnia eupatoroides*; Ppu - *Petalostemum purpureum*; Aps - *Ambrosia psilotachya*; Sun - *Schrankia uncinata*; Eca - *Erigeron canadensis*; Aster - *Aster* spp.; Ala - *Achillea lanulosa*; Lpu - *Liatrus punctata*; Psc - *Panicum scribnerianum*; Ost - *Oxalis stricta*; Cov - *Ceanothus ovatus*; Sin - *Silphium integrifolium*.

(c) IF = intensity of feeding (average of 3 replicates). A = no feeding; B = trace to 1/2 of plant eaten; C = 1/2 plus; D = eaten entirely.

(d) One or more plants completely consumed in one or two replicates; letter grades indicate average degree of injury in 3 replicates.

Table 7. Number of Melanoplus femurrubrum femurrubrum (DeGeer) resting and feeding on Andropogon scoparius (Asc) compared to various other species of plants at different times and temperatures during the day, and rating of feeding injury at 48 hours.

Time	°F.	(a)	Asc	Keu[b]	Asc	Ppu	Asc	Aps	Asc	Aster	°F.	Asc	Sun	Asc	Vba	Asc	Aca	Asc	Eca
5 pm	85	R	4	1	3	0	8	2	0	5	86	5	1	2	7	1	0	3	6
		F	2	1	1	0	6	1	0	5		4	1	1	7	1	0	3	2
7 am	74	R	2	3	0	3	1	5	3	5	68	2	1	0	7	1	0	2	4
		F	2	3	0	3	1	5	3	4		2	0	0	7	1	0	1	2
12 noon	79	R	3	1	1	3	1	4	1	3	73	0	1	2	2	1	1	0	5
		F	1	0	0	3	0	1	0	3		0	0	1	0	1	1	0	5
5 pm	80	R	3	2	1	4	2	2	0	2	83	0	0	2	0	0	1	1	0
		F	2	2	1	4	1	2	0	1		0	0	2	0	0	1	0	0
7 am	73	R	0	1	0	2	0	2	2	3	66	3	0	0	5	0	4	0	5
		F	0	0	0	0	0	2	1	2		3	0	0	5	0	4	0	4
Average		R	2.4	1.6	1.0	2.4	2.4	3.0	1.2	3.6		2.0	0.6	1.2	4.2	0.6	1.2	1.2	4.0
		F	1.4	1.2	0.4	2.0	1.6	2.2	0.8	3.0		1.8	0.2	0.8	3.8	0.6	1.2	0.8	2.6
		IF[c]	C+	A-	C+	B-	C	B+	C+	C		B	A	B	B-	B	C+	B+	C-[d]
			Asc	Sin	Asc	Artem	Asc	Ael	Asc	Ala		Asc	Bcu	Asc	Kcr	Asc	Psc	Asc	Lpu
5 pm	72	R	0	3	1	4	1	1	1	3	78	1	0	3	2	4	8	4	2
		F	0	2	1	3	1	1	0	2		0	0	1	2	1	2	1	0
7 am	62	R	0	5	2	5	0	4	1	8	72	2	0	1	3	0	0	1	3
		F	0	4	1	3	0	3	0	4		1	0	1	1	0	0	0	0
12 noon	75	R	0	0	0	3	0	1	1	1	62	1	2	1	3	1	0	2	1
		F	0	0	0	1	0	1	1	1		0	0	0	0	0	0	0	0
5 pm	76	R	0	0	1	1	0	2	2	3	63	0	0	0	1	1	0	0	4
		F	0	0	1	1	0	0	1	3		0	0	0	0	0	0	0	0
7 am	68	R	2	4	3	0	2	2	1	8	54	1	1	1	2	1	1	0	4
		F	1	4	0	0	2	2	1	7		0	0	0	0	0	0	0	0

Table 7. (cont.)

Time	°F.	(a)	Asc	Sin	Asc	Artm	Asc	Ael	Asc	Ala	°F.	Asc	Bcu	Asc	Kcr	Asc	Psc	Asc	Lpu
12 noon	66	R	1	9	1	2	1	3	0	5	-	-	-	-	-	-	-	-	-
		F	1	7	1	2	0	2	0	5		-	-	-	-	-	-	-	-
Average		R	0.5	3.5	1.3	2.5	0.7	2.2	1.0	4.7		1.0	0.6	1.2	2.2	1.4	1.8	1.4	2.8
		F	0.3	2.8	0.7	1.7	0.5	1.5	0.5	3.7		0.2	0	0.4	0.6	0.2	0.4	0.2	0
		IF	B+	B-	B+	B+	A	C	A-	B		B	B-	B-	B	B	C	B-	B
			Asc	Cov	Asc	Pfl						Asc	Ost						
5 pm	78	R	3	4	6	0					55	0	0						
		F	1	1	5	0						0	0						
7 am	69	R	4	1	6	3					53	1	0						
		F	4	1	5	2						0	0						
12 noon	86	R	3	0	0	1					58	1	0						
		F	3	0	0	0						0	0						
5 pm	90	R	3	3	1	0					56	0	4						
		F	2	1	0	0						0	0						
7 am	70	R	1	4	0	2					50	0	0						
		F	1	3	0	0						0	0						
Average		R	2.8	2.4	2.6	1.2						0.4	0.8						
		F	2.2	1.2	2.0	0.4						0	0						
		IF	C	B	B	B						B	B						

(a) R = number of grasshoppers resting on plants (total of 3 replicates).
F = number feeding (total of 3 replicates).

Table 7. (concl.)

(b) Asc - <u>Andropogon scoparius</u>; Keu - <u>Kuhnia eupatoroides</u>; Ppu - <u>Petalostemum purpureum</u>; Aps - <u>Ambrosia psilotachya</u>; Aster - <u>Aster</u> spp.; Sun - <u>Schrankia uncinata</u>; Vba - <u>Vernonia baldwini</u>; Aca - <u>Amorpha canescens</u>; Eca - <u>Erigeron canadensis</u>; Sin - <u>Silphium integrifolium</u>; Artem - <u>Artemesia</u> spp.; Ael - <u>Ambrosia elatior</u>; Ala - <u>Achillea lanulosa</u>; Bcu - <u>Bouteloua curtipendula</u>; Kcr - <u>Koeleria cristata</u>; Psc - <u>Panicum scribnerianum</u>; Lpu - <u>Liatris punctata</u>; Cov - <u>Ceanothus ovatus</u>; Pfl - <u>Psoralea floribunda</u>; Ost - <u>Oxalis stricta</u>.

(c) IF = intensity of feeding (average of 3 replicates). A = no feeding; B = trace to 1/2 of plant eaten; C = 1/2 plus; D = eaten entirely.

(d) One or more plants completely consumed in one or two replicates; letter grade indicates average degree of injury in 3 replicates.

Table 8. Summary of feeding of Melanoplus femurrubrum femurrubrum (DeGeer) on various plant species compared to seven base plants.(1)

Base Plants	Ael[2]	Aster	Ala	Eca	Aps	Pfl	Sin	Vba	Artem	Lpu	Sun	Ppu	Ost	Keu	Rci
	FORBS														
Big bluestem (Age)	>	>	>	>	>	>	>	=	>	=	=	>	(a)	<	=
Sand dropseed (Scr)	>	>	(a)	>	>	>	>	=	=	>	<	<	<	<	(a)
Switchgrass (Pvi)	>	>	>	>	>	>	>	=	>	>	<	<	<	<	(a)
Indiangrass (Snu)	>	>	>	>	>	>	>	>	>	<	>	<	(a)	<	(a)
Sideoats grama (Bcu)	>	>	>	(a)	>	(a)	(a)	>	<	=	=	>	=	<	(a)
Prairie junegrass (Kcr)	>	>	>	>	>	>	<	>	<	>	>	=	<	=	(a)
Little bluestem (Asc)	>	>	>	>	<	=	>	>	=	<	<	<	=	<	(a)

Base Plants	Scr	Psc	Snu	Pvi	Asc	Bcu	Kcr	Aca	Cov
	GRASSES							WOODY PLANTS	
Big bluestem (Age)	>	=	=	=	<	<	<	>	<
Sand dropseed (Scr)	(a)	<	>	<	<	<	<	<	<
Switchgrass (Pvi)	>	=	<	(a)	>	<	<	>	=
Indiangrass (Snu)	<	>	(a)	>	<	<	<	>	>
Sideoats grama (Bcu)	>	>	>	>	>	(a)	=	=	>
Prairie junegrass (Kcr)	>	>	>	>	>	=	(a)	>	<
Little bluestem (Asc)	>	>	>	<	(a)	>	<	>	<

(1) > — feeding damage greater than that on base plant.
< — feeding damage less than that on base plant.
= — feeding damage equal to damage on base plant.
(a)— not evaluated.

Table 8. (concl.)

(2) Ael - Ambrosia elatior; Aster - Aster spp.; Ala - Achillea lanulosa; Eca - Erigeron canadensis; Aps - Ambrosia psilostachya; Pfl - Psoralea floribunda; Sin - Silphium integrifolium; Vba - Vernonia baldwini; Artem - Artemesia spp.; Lpu - Liatris punctata; Sun - Schrankia uncianata; Ppu - Petalostemum purpureum; Ost - Oxalis stricta; Keu - Kuhnia eupatorioides; Rci - Ruellia ciliosa; Scr - Sporobolus cryptandrus; Psc - Panicum scribnerianum; Snu - Sorghastrum nutans; Pvi - Panicum virgatum; Asc - Andropogon scoparius; Bcu - Bouteloua curtipendula; Kcr - Koeleria cristata; Aca - Amorpha canescens; Cov - Ceanothus ovatus.

PLATE VII

Insectary in which cage studies of <u>Melanoplus femurrubrum femurrubrum</u> (DeGeer) food preferences were conducted.

PLATE VII

PLATE VIII

Cage used to study food preference and behavior of grasshopper species between plant species.

PLATE VIII

PLATE IX

Damage by Melanoplus femurrubrum femurrubrum (DeGeer) on Panicum virgatum and Achillea lanulosa.

Fig. 1. Before feeding.

Fig. 2. After feeding.

PLATE IX

Fig. 1.

Fig. 2.

PLATE X

Damage by _Melanoplus_ _femurrubrum_ _femurrubrum_ (DeGeer) on _Sporobolus_ _cryptandrus_ and _Erigeron_ _canadensis_.

Fig. 1. Before feeding.

Fig. 2. After feeding.

PLATE X

Fig. 1.

Fig. 2.

PLATE XI

Damage by *Melanoplus femurrubrum femurrubrum* (DeGeer) on *Sporobolus cryptandrus* and *Ambrosia elatior*.

Fig. 1. Before feeding.

Fig. 2. After feeding.

PLATE XI

Fig. 1

Fig. 2.

PLATE XII

Damage by *Melanoplus femurrubrum femurrubrum* (DeGeer) on *Koeleria cristata* and *Ambrosia elatior*.

Fig. 1. Before feeding.

Fig. 2. After feeding.

PLATE XII

Fig. 1.

Fig. 2.

PLATE XIII

Damage by *Melanoplus femurrubrum femurrubrum* (DeGeer) on *Andropogon scoparius* and *Vernonia baldwini*.

Fig. 1. Before feeding.

Fig. 2. After feeding.

PLATE XIII

Fig. 1.

Fig. 2.

PLATE XIV

Damage by <u>Melanoplus femurrubrum femurrubrum</u> (DeGeer) on <u>Andropogon gerardi</u> and <u>Erigeron canadensis</u>.

Fig. 1. Before feeding.

Fig. 2. After feeding.

PLATE XIV

Fig. 1.

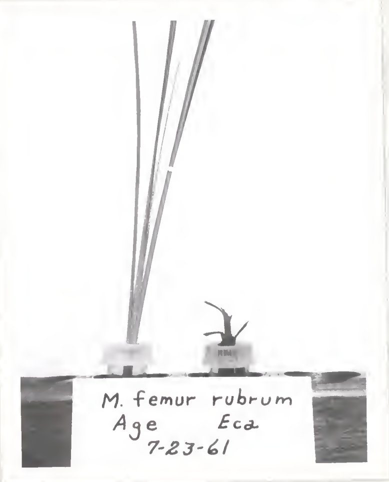


Fig. 2.

PLATE XV

Damage by Melanoplus femurrubrum femurrubrum (DeGeer) on Sporobolus cryptandrus and Andropogon scoparius.

Fig. 1. Before feeding.

Fig. 2. After feeding.

PLATE XV

Fig. 1.

Fig. 2.

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FOOD PLANTS OF *MELANOPLUS FEMURRUBRUM FEMURRUBRUM* (DEGEER) IN THE BLUESTEM GRASS REGION OF KANSAS

by

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Food plants and relationships of grasshopper species and plant species in bluestem pastures are not well understood. This report is the result of cage studies on food plant preferences conducted during the summer growing season of 1961 on *Melanoplus femurrubrum femurrubrum* (DeGeer).

Initial selection of plants to be evaluated, was based upon calculation of a correlation coefficient between each plant species population density, and grasshopper species population density.

Cage studies were conducted in an outdoor insectary. Twenty grasshoppers of a given species and plant species were placed in each cage. The grasshoppers were given the opportunity to feed for 48 hours on either or both of two plants for a given time period. Plants were replaced if completely consumed. After 48 hours the plants were removed and replaced by another series of two plant species. Species of grasses vs. grasses, and grasses vs. forbs, were evaluated. A total of nine perennial grasses, 14 perennial forbs, two annual forbs, and two woody plants were used in the cage studies. A total of 64 plant species were used in correlation studies. Counts were made three or four times per day during the 48-hour period, recording total number of grasshoppers (1) resting on the plants; and (2) feeding on plants. Photographs also were taken of the plants immediately after removal from the cage. The photographs were ranked according to the intensity-of-feeding as compared with before-feeding pictures. A grade of A, B, C and D was used: A = no feeding; B = trace to 1/2 of plant eaten; C = 1/2 plus eaten; D = eaten entirely.

Preferred most over big bluestem were: aster, horseweed, common ragweed and scurfpea. All four plants were completely consumed in each of three replicates.

Preferred most over sand dropseed were: horseweed, aster, dotted gayfeather and wholeleaf rosinweed. Horseweed was completely consumed in each of three replicates.

Preferred most over switchgrass were: western yarrow, sagewort, horseweed and dotted gayfeather. Western yarrow was completely consumed in each of three replicates.

Preferred most over indiangrass were: wholeleaf rosinweed, horseweed, baldwin ironweed and western yarrow.

Preferred most over sideoats grama were: aster, common ragweed, purple prairieclover and western ragweed. Aster and common ragweed were completely consumed in each of three replicates.

Preferred most over prairie junegrass were: common ragweed, scurfpea, aster and western yarrow.

Preferred most over little bluestem were: western yarrow, baldwin ironweed, horseweed and aster.

Horseweed appeared in the four most preferred plants in each case except sideoats grama, in which case horseweed was not evaluated.

The work reported on here is considered a first step in obtaining clues as to preferred plant species which might be used in interpreting the reason for associations which exist between grasshopper and plant species, particularly in the bluestem regions of Kansas.