KANSAS BLISTER BEETLES (COLEOPTERA: MELOIDAE): HISTORICAL AND ALFALFA FIELD SURVEY RESULTS

by

SUE LENSSEN BLODGETT

B.S., Syracuse University, 1974
M.S., Cornell University, 1980

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Entomology

KANSAS STATE UNIVERSITY
Manhattan, Kansas
1987

Approved by:

Major Professor

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PART II.

ACKNOWLEDGEMENTS

I would like to thank my committee members Dr. Alberto Broce and Dr. Derrick Blocker for their continuing interest and support during my degree program. Special thanks are due to Dr. Randy Higgins for his welcome enthusiasm and holistic approach to training graduate students, encouraging personal growth as well as scientific achievement. Ken Parker, Norm Hupe, Alberto Wood, George Leonard, Vincent and Ricki Borg, and Ron Strauss allowed me to sample their alfalfa fields. Dr. George Byers, curator of the Snow Collection at the University of Kansas for setting aside time and space. Dr. George Milliken, Dr. Dave Hagstrum, and Jeff Crabb gave me invaluable statistical advice. Barb Paxson, Denise Carlson, and Sandy Vap who cheerfully helped with the field work and processing hay samples. Marlin Rice, Lou Wooten, Larry Corpus, Tim Gibb and Mike Grodowitz for their encouragement and advice. My heartfelt thanks to my patient and supportive husband, Andrew Lenssen.

To my husband, Andy
and our daughter, Susan Louise

LITERATURE REVIEW

I. Alfalfa

Alfalfa hay compares favorably with corn silage as a high quality source of energy and protein. Protein levels of from 15 to 20 percent and relatively high carotene content help make alfalfa a superior feed source for milk and meat production in the livestock industry (Hanson & Davis 1975). It is used as a food source in baled, pelleted, or cubed forms by the livestock, horse, and animal feed industry. Approximately 11,000,000 ha are grown throughout the United States (Barnes & Sheaffer 1985). Kansas ranks ninth in the United States for alfalfa production with over 1 million ha in production (Kastens 1984).

Alfalfa is a perennial crop which is harvested for forage four or more times per year, depending on the climate. Much of the diversity in production practices and in geographic, environmental, and climatic conditions throughout the central United States is represented by alfalfa production areas within Kansas. Eastern Kansas conditions are similar to other midwestern states whereas western Kansas conditions are more similar to the southwestern United States. Significant portions of hay grown in midwest and southwest regions are shipped to other parts of the country.

A ten-stage numerical system has been developed for determining the phenological growth and developmental stages of alfalfa (Kalu & Fick 1981). Three vegetative stages are designated 0, 1, and 2 with corresponding stem lengths (measured to the nearest cm) of less than or equal to 15 cm., between 16 and 30 cm., or greater than 31 cm, respectively. Early bud alfalfa, designated stage 3, has stems with buds at 1 or 2 nodes. Late bud alfalfa, stage 4, has stems with buds on 3 or more nodes. Early flower alfalfa, stage 5, has stems with one open flower. Late flower alfalfa, stage 6, has stems with at least two nodes that support open flowers. Early, late, and ripe seed alfalfa, stages 7, 8, and 9, respectively, are characterized by 1 to 3 nodes with green seed pods, greater than or equal to 4 nodes with green seed pods, and nodes with mostly mature brown seed pods.

II. Meloidae

There are approximately 2,300 species of blister beetles found throughout warm, temperate parts of the world (Van Dyke 1928, Weatherston & Percy 1978). North America is well-represented, with 300 Meloidae species occurring in the continental United States (Sutherland 1983). Surveys of blister beetle species have been conducted in Arizona (Werner et al. 1966), Arkansas (Horsfall 1943), Kansas (Milliken 1921), Oklahoma (Arnold 1976), South Dakota (Carruth 1931), Texas (Dillon 1952), and Utah (Selander 1951). A number of these studies summarized label information from pinned specimens, including collection dates, locations of occurrence, host plants, and provided a key to locally occurring species (Carruth 1931, Dillon 1952, Arnold 1976).

The Kansas study by Milliken (1921) included field surveys conducted from March 1913 to May 1915 near Garden City, KS and from June 1915 to June 1917 near Wichita, KS. The author noted that although cultivation has enabled grasshoppers to become more widely distributed, it has not been accompanied by a corresponding increase in blister beetle densities. This relationship might have been expected because immature blister beetles are predators of grasshopper eggs. Furthermore, Milliken (1921) concluded that blister beetle larval populations were not able to suppress grasshopper populations enough to offset their detrimental effects as crop pests. Milliken included a key to the following species collected at Garden City: *Macrobasis segmentata* Say, *M. albida* Say, *M. unicolor* Kirby, *M. immaculata* Say, *Epicauta cinerea* Forster, *E. corvina* LeConte, *E. funebris* Horn., *E. pennsylvanica* DeGeer, *E. lemniscata* F., *E. maculata* Say, *E. pardalis* LeConte, *E. marginata* F., *E. callosa*

LeConte, E. ferruginea Say, and E. sericans LeConte.

A 1948 insect population survey (Smith & Dean 1950) indicated that blister beetles were numerous throughout Kansas, although less numerous than they had been in 1947. Blister beetles caused injury to garden crops and to alfalfa in southeastern Kansas in 1948. The 'striped' species was cited as economically important over most of the state.

The Arizona study (Werner et al. 1966) included a key to 143 Meloidae species. In addition to a description of each species, information regarding bionomics, food plant preference, behavior, and known range was included.

Horsfall (1943) attempted to follow blister beetle populations in Arkansas over time. Development of blister beetle identification keys, morphological descriptions, and ecological observations summarize his other contributions.

The Utah survey (Selander 1951) was primarily a taxonomic effort describing blister beetles in museum and field collections. Bionomic information was collected as field collections were made.

Several species of blister beetle are distributed throughout Canada. They are rarely observed as crop pests on either coast. Occasional outbreaks of these insects occur on crops in Ontario and Quebec. In the

Prairie Provinces (Manitoba, Saskatchewan, and Alberta) and eastern British Columbia these beetles occur most frequently as crop pests (Manson 1948).

Several efforts to revise taxa at the family, subfamily, and genus level have been made (Werner 1953, Werner 1954, Selander 1954, Selander 1955, Enns 1956, Werner 1958, Selander 1960, Selander & Mathieu 1969, Pinto & Selander 1970). A reclassification of the family Meloidae was accomplished by Van Dyke in 1928. The availability of additional specimens of Meloidae has made several changes in the taxonomy necessary (Enns 1956, Werner 1953). A study of the cladistic and phenetic relationships among genera has resulted in only one well-researched subtribe, Eupomphina (Pinto 1984). The 26 beetles in this taxon are confined to the southwestern United States. This type of analysis was possible because these species are well known taxonomically. Currently, a revision of the genus Epicauta is ongoing (Pinto, Univ. of California, Riverside, personal communication).

A taxonomic revision of seven of thirty-one species belonging to the vittata group has been completed (Adams & Selander 1979). These 'striped' blister beetles are endemic to North America. Extensive information on the biology, ecology, behavior, and reproductive biology was included.

These species are well-known pests of potatoes, alfalfa, and other crops that occur commonly in Kansas. This group is of special interest because of their implications in cantharidin toxicosis. Adult behaviors (feeding, sexual, etc.) were described in detail and collection of data was supplemented through the use of motion pictures. Field collected adults also were used in laboratory tests of feeding preference and hybridization. Examination of records indicate E. occidentalis has extended its range beyond the Great Plains or increased its population density to detectable levels in Illinois, Tennessee, and Mississippi during this century. This species has been remarkably successful in colonizing highly ecologically-disturbed areas including farming communities, pastures, roadsides, and vacant lots.

A systematic study of the albida group reported one species found occasionally in Kansas (Selander & Mathieu 1969). E. immaculata ranges from west of the Appalachian Mountains to the Rio Grande River and from South Dakota well into Mexico, although the latter is not well documented. Ecological, behavioral, and anatomical observations of E. immaculata were included.

It was originally thought by Selander and Mathieu that population density declines of two albida group species, _E_. _segmenta_ and _E_. _validae_ were influenced by a reduction of Midwest potato acreages during the late 1940's. The authors also felt that destruction of natural habitats and use of insecticides contributed to the decline of these blister beetle populations by modifying grasshopper populations. _E_. _immaculata_ has been noted feeding on host plants in the families Asclepiadaceae, Chenopodiaceae, Compositae, Cruciferae, Leguminosae, Solanaceae, Zygophyllaceae.

Host specificity can influence management recommendations regarding blister beetle control. Historically, observers have noted that blister beetles prefer to feed on the petals and pollen of several cultivated crops. Hosts include: potatoes (_Solanum tuberosum_ L.), sugar beets (_Beta vulgaris_ L.), alfalfa, bean (_Phaseolus_ spp.), peanut (_Arachis hypogaea_ L.), sweet clover (_Melilotus_ spp.), Russian olive trees (_Elaeagnus angustifolia_ L.), and native plant hosts including: sunflower (_Helianthus_ spp.), goldenrod (_Solidago_ spp.), scurf pea (_Psoralea tenuiflora_ Pursh) and other prairie legumes (Milliken 1921). However, Werner et al. (1966) stated that the food-plant preference of adult Meloidae may appear narrow when a preferred host is present and very general when preferred plants are not available, making simple determinations of host preference difficult. Selander (1951) noted that in general Leguminosae and Compositae were the favored host plants of Meloidae collected in Utah. Ten blister beetle species were described as serious garden and forage crop pests because they feed on leaves and flowers (Gates & Peters 1962).

E. pennsylvanica was found abundantly on goldenrod throughout the fall in Georgia (McLain 1982). Population declines of E. pennsylvanica on goldenrod were observed beginning 24 September (Mathwig 1968). Temperature decreases and a decline in goldenrod and aster flowers influenced blister beetle densities. E. fabricii, E. vittata, and E. pestifera were used in a laboratory choice test in which two compounds found in sweetclover, coumarin and cis-o-hydroxycinnamic acid, were shown to be feeding deterrents (Gorz et al. 1972).

E. vittata and E. fabricii were observed preferentially defoliating plants of glandless cotton varieties while glanded cotton plants remained undamaged (Maxwell et al. 1965). The Maxwell et al. study hypothesized that decreased gossypol content and related biochemical changes were responsible for increased preference of glandless plants.

The family Meloidae undergoes hypermetamorphosis. The first instar, triungulins, actively seek a suitable prey on which suceeding larval stages will feed (Borror et al. 1981). If the first instar is successful in finding a suitable host, subsequent instars sucessfully molt into increasingly immobile forms (Werner et al. 1966). First instars have been described (Pinto 1972, Pinto 1977, Agafitei & Selander 1980), using terminology developed by MacSwain (1956). These efforts will facilitate classification of some Meloidae taxon. A reveiw of the bionomics and taxonomy of 12 species of western North American Epicauta belonging to the Maculata Group was compiled by Pinto (1980). Adults of this group have a characteristic spotted pattern on their elytra. The species are known to occur in Kansas although no records report them occurring in alfalfa (KSU Insect Collection, Manhattan, KS and Snow Insect Collection, Lawrence, KS).

Aggregations or swarms have been observed in several species of blister beetles, some of which occur in alfalfa. Swarms of E. occidentalis were noted in Stephens County, Oklahoma on 27 May 1986 (Arnold 1986). Aggregations of two blister beetle species were observed in southwest United States (P. Miller, Oklahoma State Univ., personal communication). Aggregations of the striped blister beetle, E. lemniscata, have been noted in nearly all soybean fields of southwestern Louisiana (Ingram & Douglas 1932) and in Arkansas alfalfa fields (Horsfall 1942). *Lytta magister* and *Tegrodera aloga* have been observed in large mating aggregations in the Sonoran desert (Snead & Alcock 1985).

Immature Meloidae have been known as grasshopper egg predators for many years (Lavigne & Pfadt 1965). Parker and Wakeland (1957) reported that predation of grasshopper eggs is greater in cultivated than native grassland areas. Egg predation in the seven Midwestern states surveyed was 17.87 percent. Blister beetles accounted for nearly half (8.80 percent) of the predation. This grasshopper egg predator survey included sites near Garden City and Hays, KS. Blister beetles were responsible for 3.66 percent of the total 10.49 percent predation in the Kansas locations. A decrease in the populations of blister beetle larvae was thought to be related to a concomitant local decline of grasshopper populations (Lavigne & Pfadt 1965). Gilbertson and Horsfall (1940) noted that a rise in grasshopper abundance was followed by a similar rise in blister beetle populations. Grasshopper abundance has been related historically to hot and dry conditions (Riegert 1968).

Meloidae utilizing bees as larval hosts belong to the subfamilies Meloinae and Nemognathinae. These blister beetles are known to use the hymenopterous families Anthophoridae and Megachilidae, respectively, as larval food sources (Erickson et al. 1976, Linsley & MacSwain 1942).

Meloidae larvae in the genus Lytta are predators of the sweat bee Agapostemon virescens (Eickwort 1981), a gregarious ground nesting anthophorid (Linsley & MacSwain 1952), and a sand-dwelling leaf-cutter bee Megachile (Xeromegachile) rubi (Eickwort et al. 1981).

Certain Meloidae larvae prey on eggs of their own family. Eggs of Epicauta pennsylvanica were found to be acceptable hosts for the larvae of E. atrata (Selander 1981, Selander 1982). This finding represents the third group of larval prey to be identified as hosts for immature blister beetles. Other genera, including Pleuropompha and Mylabris, are thought to also utilize Meloidae eggs as food.

Cantharidin and dead Meloids have been used in traps to attract various Anthicidae (Chandler 1976). Insects in the orders Hemiptera, Coleoptera, Diptera, and Hymenoptera were collected when cantharidin was used as a bait (Young 1984a, Young 1984b).

III. Cantharidin

Cantharidin is the toxin present in the blister beetle body. It is a known vesicant and has been used for its aphrodisiac qualities for centuries. Lytta vesicatoria, a common European species, is the source of the active ingredient of Spanish fly (Werner et al. 1966). Recently, Meloid beetles were reported to be available in a Chinese drugstore (Kritsky 1987). Case histories have been written of human poisoning by cantharidin (Nickolls & Teare 1954, Craven & Polak 1954). The lethal dose for humans is reported to be 65 mg compared with 162.5 mg as the lethal dose for arsenic (Smit 1954).

At one time blister beetle toxicosis was thought to be a regional problem, limited to the southwestern United States. However, it has recently been reported with increasing frequency in the Midwest (Scoggins 1981, Rich 1984). The defensive role of cantharidin is well-known (Crowson 1981). Beetles bleed reflexively from leg joints when disturbed. Secretions cause the blistering characteristic of contact with body fluids of Meloid beetles. Oedemerid beetles also are known to contain cantharidin (Carrel et al. 1986b).

Cantharidin is an irritant and nephrotoxin that causes blistering of skin and mucous membranes (Scott 1962). Livestock, especially horses, are poisoned when they eat dead, crushed beetles found in baled alfalfa hay (Oehme 1981, J. Schneider, Kansas State

Univ., College of Vet. Med., personal communication). Signs vary from mild to acute illness and ultimately can result in the animal's death (Bahme 1968, Schoeb & Panciera 1978, Blake 1984, Rollins 1985).

Feeding blister beetle infested hay can have catastrophic results for alfalfa producers, hay brokers, and livestock owners. There are many documented cases of livestock poisoning, particularly of horses, following ingestion of blister beetle contaminated alfalfa hay (Schoeb & Panciera 1978, Beasley et al. 1983, Rollins 1985). No antidote is known and treatment is primarily symptomatic including maintaining electrolyte balance, administration of fluids, and protection of the gastrointestinal mucous membranes to prevent further absorption (Schoeb & Panciera 1978).

Ingestion of cantharidin can be devastating to the animal. Postmortem clinical manifestations suggesting cantharidin poisoning include sloughing of the digestive epithelium, nephritis, hemorrhagic cystitis, and myocardial necrosis (Schoeb & Panciera 1978). The toxic effects are not restricted to horses, although they may be more sensitive than cattle or sheep because of differences in their digestive systems. Poisoning of ruminants has been reported by Ray et al. (1980). Poisonings have been reported in Oklahoma

(Dunlap 1983), Arizona (Rollins 1985), Texas (Bahme 1968), Tennessee (Moore 1963), Florida (MacKay & Wollenman 1981), and Kansas (F. Oehme, Kansas State Univ., College of Vet. Med., personal communication) indicating that the problem is of national importance.

Distribution and biosynthesis of cantharidin among males and females have not been completely resolved. Crowson (1981) states that cantharidin occurs in the hemolymph of both sexes. However, most researchers agree that cantharidin is synthesized only by the males and is transferred to females during copulation (Sierra et al. 1976). Biosynthesis studies have shown that male Lytta polita transfer approximately 70 percent of their cantharidin reserves during mating (Carrel et al. 1986a). Approximately one-third of the cantharidin transferred was from the reproductive system and the remaining two-thirds was derived from other body reserves. Four days after mating, cantharidin reserves in males were restored to approximately premating levels.

Cantharidin content varies considerably among species of field collected blister beetles occurring in Colorado (Capinera & Stermitz 1984). Capinera and Stermitz (1984) measured cantharidin levels of six blister beetles that occur in Colorado alfalfa and compared them with three species from other genera not usually found in alfalfa. E. fabricii, E. pennsylvanica, E. sericans, and E. immaculata had cantharidin levels of 2.1 and 6.6; 0.6 and 1.7; 1.6 and 6.6; and 4.1 and 5.8 percent (dry-weight) for females and males of each species, respectively. They found that females generally had lower cantharidin concentrations consistent with the reports that males biosynthesize the toxin and pass it to the females during copulation. There was considerable variation among samples within a species. These authors hypothesize that mating status determines a female's cantharidin concentration and can explain some of the variability in cantharidin levels. Three separate populations of the same blister beetle species (E. lemniscata) were found to have 0.89, 5.4, and 3.06 percent cantharidin by dry weight (Ray et al. 1979). E. pestifera has been found to contain 1.09 percent cantharidin by weight of dried beetles (Walter & Cole 1967).

A Colorado study measured cantharidin contents of field-collected blister beetles (J. Capinera, Colorado State Univ., personal communication). Preliminary results from the study noted significant variability within species. Recent efforts in Colorado include documenting the cantharidin levels in blister beetle eggs (S. Klahn, Colorado State Univ., personal communication).

Cantharidin levels have been quantitatively determined using different analytical methods, including gas-liquid chromatography (Bagatell et al. 1966), high pressure liquid chromatography (HPLC) (Ray et al. 1979, Capinera et al. 1985), infrared, NMR spectroscopy and thin layer chromatography (Walter & Cole 1967, Salama et al. 1974). Gas chromatography (Rollins 1985) has been used to document cantharidin in horse urine. HPLC is used routinely for detecting the presence of cantharidin in urine and stomach samples (J. Reagor, Texas A & M, Vet. Med. Diagnostic Lab., College Station, personal communication).

Lethal doses of cantharidin have been estimated at 15 and 4 g of a 1 percent cantharidin concentration for horse and sheep, respectively (Clark et al. 1972) and 1 g of ground blister beetles for a pony (Bahme 1968). As few as 5 to 10 beetles, or up to 100 beetles or more may cause death of horses (Shawley et al. 1982). Doses of 4, 5, and 6 g of air-dried ground blister beetles were fatal to horses weighing 270, 326, and 405 kg, respectively (Panciera 1972). Doses of 3 g caused illness but not death in 2 horses weighing 164 and 315 kg (Panciera 1972).

Horse death was reported 4 hours following an oral dose of 27 mg/kg of ground blister beetles (total dose of 5 g). Another horse died 6 hours after a dose of 18 mg/kg of ground blister beetles was consumed (total dose of 6 g; Schoeb & Panciera 1978). A lethal dose of 0.5 to 1.0 mg of cantharidin/kg body weight is commonly cited (Capinera & Sternmitz 1984, Blake 1984).

Mild blister beetle poisoning may be more common than is suspected because some animals recover from the anorexia, low fever, and mild colic without diagnosis or treatment (Rollins 1985). This also may be particularly true for cattle and sheep because less attention is given to individual animals and the frequency of necropsy to determine cause of death is lower.

IV. Pest Management Implications

Cooperative Extension Service publications which address blister beetle-related concerns are available in many states (Scoggins 1981, Henry 1983, Blodgett & Sutherland 1984, Bauernfiend & Breeden 1984).

Blister beetles implicated in many horse poisonings include several 'striped' species, *Epicauta vittata*, *E. occidentalis*, and *E. lemniscata*, (Moore 1963, Bahme 1968, Panciera 1972, Sippel 1976, Schoeb & Panciera 1978, MacKay & Wollenman 1981, Shawley et al. 1982), *E. pardalis* (Rollins 1985), *E. pestifera*, the marginated blister beetle (Scoggins 1981) and _E. pennsylvanica_, (Beasley et al. 1983). Although several additional species have been cited in the literature most authors agree that blister beetles belonging to the _Epicauta_ genus are to blame for the vast majority of livestock deaths. _E. vittata_ was implicated in a poisoning (Panciera 1972) in which 145 g of dried beetles were recovered from a 2.34 kg flake of hay.

Blister beetle control using 0.34 kg carbaryl in 188 l of water per ha was found to be 100 percent effective in causing mortality 24 hr after application with a ground sprayer (P. Miller 1986, Oklahoma State Univ., personal communication). Treatment of striped blister beetle, _E. lemniscata_, aggregations with a 2 percent rotenone dust was 79 to 97 percent effective in killing the beetles (Horsfall 1942). Horsfall suggested applying a ring of dust in a large circle to surround the swarm and then dust in concentric circles from the outside to the center.

The increase in horse poisonings by blister beetles in recent years often is attributed to coincidental adoption of the crusher-crimper in hay harvesting. It has been hypothesized that crimpers crush beetles into the cut alfalfa, thereby ensuring their incorporation into the final baled product

(Coppock 1981, Oehme 1981).

A three-pronged program designed to produce blister beetle free alfalfa has been promoted by Blake (1984). Management includes revising hay making methods and applying an insecticide (carbaryl) to eradicate the grasshoppers which serve as immature blister beetle hosts. The insecticide is applied once per cutting, 14 days before harvest, regardless of grasshopper populations. The alfalfa is cut with a mower conditioner and is crimped but not windrowed. The following morning the hay is raked into windrows, theoretically allowing blister beetles killed during mowing to be shaken out of the hay. An alfalfa producer following this protocol received a premium of 27.5 to 33 dollars per metric ton from horsemen buying the hay. However, no validation that the approach actually reduced poisoning risks was presented.

Blister beetles are most likely to occur in the first and second cuttings of alfalfa hay in Arizona. Inspection of hay designated as horse feed, avoidance of crimping alfalfa in fields adjoining uncultivated land, delaying baling after cutting, and use of insecticides are practices recommended in Arizona to avoid cantharidin-induced poisoning (Henry 1983). Recommendations of the New Mexico State University Cooperative Extension Service for purchase or use of alfalfa by horse feeders include obtaining alfalfa cut before mid-May or after late August, buying hay which has been scouted regularly by trained personnel, and inspecting alfalfa for blister beetles as it is removed from the bale (Blodgett & Sutherland 1984). The Oklahoma Cooperative Extension Service recommends knowing the alfalfa supplier, determining what precautions the producer might have taken to avoid blister beetle contamination, inspecting hay before feeding, and, if adverse symptoms are expressed by horses eating the hay, calling a veterinarian immediately (Shawley et al. 1982).

Entomological field surveys continue in Oklahoma (P. Miller, Oklahoma State Univ., personal communication) and Kansas (Bell 1984). The Kansas survey is part of a routine state-wide survey of economic pests covering all major field crops, is published weekly during the summer by the Kansas State Board of Agriculture and is entitled The Kansas Cooperative Economic Insect Survey Report. The Oklahoma Alfalfa Integrated Pest Management program is responsible for surveying fields for alfalfa weevils, aphids, and lepidopterous pests but has recorded some observations on blister beetle occurrence. Neither of these surveys are designed to provide the reliable population estimates needed for developing sampling and management programs.

Alfalfa hay purchased from Kansas (MacKay & Wollenman 1981, Williams 1981) and Illinois (Beasley et al. 1983) has been specifically implicated in poisoning cases. One prominent member of the horse industry suggested that alfalfa hay from Kansas should not be considered as possible horse feed until the blister beetle problem is solved (Williams 1981).

Alfalfa producers, brokers, and animal health specialists from many other states (including Missouri, Oklahoma, Texas, New Mexico, and Colorado) have repeatedly voiced concerns over the need for more research on the problem of blister beetle incorporation into baled alfalfa. Yet little quantified information on the subject was located in the published literature.

In the past few years, some states have had their out-of-state hay market reduced because buyers feared they were purchasing blister beetle-contaminated alfalfa. The problem has become so severe in the Wichita, KS area that veterinarians have been advising horse owners to refrain from feeding alfalfa. According to one Wichita veterinarian (D. Nielson, Wichita, Kansas, personal communication) at least 6 horses are documented to have died from cantharidin toxicity during each of the last 5 years. Within a single twelve month period, 13 fatalities were recorded in the Wichita area by other local veterinarians. Livestock poisonings, such as those mentioned above, occur statewide and have been occasionally referred to the Kansas State University Veterinary Hospital for diagnosis and treatment.

Although cantharidin is recognized as a very potent toxin, little is known about its stability during storage. This is unfortunate because knowledge of cantharidin stability during hay storage could be very valuable to buyers, sellers, feeders, and processors of alfalfa hay.

Economic losses attributed to blister beetles continue to be widely publicized. The direct and indirect economic effects are interrelated and at least twofold. Direct losses are incurred when irreplaceable horses or prized livestock are poisoned or become ill after ingesting cantharidin-contaminated hay. The $ 170 million value placed on 44 stallions fed alfalfa at one Kentucky horse farm indicated the potential losses that concern these managers (Williams 1981). Indirect losses primarily affect alfalfa producers. These effects include loss of market premiums sometimes associated with 'horse-quality' hay and actual loss of an entire state market after one producer's alfalfa was implicated in a poisoning. The magnitude of indirect losses also can be great and longlasting. For instance, horses on the Kentucky farm consume 1,125 mt of horse-quality alfalfa annually. Presence of blister beetles or cantharidin in hay may preclude this use and designation. Producers experience a decline in quality by altering harvest management in attempting to avoid contamination. For instance, as late as 1 September 1986, a producer of expensive Arabian horses delayed cutting his alfalfa after determining that a significant blister beetle population was present in a standing alfalfa crop until several of the cooperators assisting with this project were consulted. Nutritional quality of alfalfa and therefore economic value decline if harvest is delayed.

LITERATURE CITED

Adams, C. L. & R. B. Selander. 1979. The biology of blister beetles of the Vittata Group of the genus Epicauta (Coleoptera, Meloidae). Bull. Am. Museum of Nat. Hist. 162: 137-266.

Agafitei, N. J. & R. B. Selander. 1980. First instar larvae of the Vittata Group of the genus Epicauta (Coleoptera: Meloidae). J. Kansas Entomol. Soc. 53: 1-26.

Arnold, D. C. 1976. Blister beetles of Oklahoma. Oklahoma State Univ. Agric. Exp. Stn. Tech. Bull. T-145.

Arnold, D. C. 1986. Oklahoma Cooperative Economic Insect Survey and Detection Report. OK State Univ. Stillwater, Oklahoma.

Bagatell, F. K., S. Ferendeci, & T. LaRonge. 1966. The determination of cantharidin in tissues and its subcellular location. J. Lab. & Clin. Med. 67: 98-107.

Bahme, A. J. 1968. Cantharides toxicosis in the equine. Southwestern Vet. pp. 147-148.

Barnes, D. K. & C. C. Sheaffer. 1985. Alfalfa, pp.89-97. In: M. E. Heath, R. F. Barnes, and D.S. Metcalfe (eds.), Forages. The science of grassland agriculture. The Iowa State University Press, Ames, IA.

Bauernfeind, R. J. & L. D. Breeden. 1984. Blister beetles. Kansas State Univ. Cooperative Extension Service, Manhattan, Kansas. Entomol. 111.

Beasley, V. R., G. A. Wolf, D. C. Fischer, A. C. Ray, & W. C. Edwards. 1983. Cantharidin toxicosis in horses. J. Amer. Vet. Med. Assoc. 182: 283-284.

Bell, K. O. 1984. Kansas cooperative economic insect survey report. Kansas State Board Agric. Summary 1984.

Blake, L. 1984. Handful of death, A horseman declares war on lethal insects in alfalfa hay. Horseman 28: 38-43.

Blodgett, S. & C. A. M. Sutherland. 1984. Blister beetles in alfalfa. New Mexico State Cooperative Extension Service. Las Cruces, NM.

Borror, D. J., D. M. DeLong, & C. A. Triplehorn. 1981. An introduction to the study of insects. 5th ed. p. 427. Saunders College Publishing Co., Philadelphia, PA.

Capinera, J. L., & F. R. Stermitz. 1984. Blister beetle update. In: Pest alert Colorado State Univ. Cooperative Extension Service 1(21): 1.

Capinera, J. L., D. R. Gardner, & F. R. Stermitz. 1985. Cantharidin levels in blister beetles (Coleoptera: Meloidae) associated with alfalfa in Colorado. J. Econ. Entomol. 78: 1052-1055.

Carrel, J. E., J. P. Doom, & J. P. McCormick. 1986a. Cantharidin biosynthesis in a blister beetle: Inhibition by 6-fluoromevalonate causes chemical disarmament. Experientia 42: 853-854.

Carrel, J. E., J. P. Doom, & J. P. McCormick. 1986b. Identification of cantharidin in false blister beetles (Coleoptera, Oedermeridae) from Florida. J. Chem. Ecol. 12: 741-747.

Carruth, L. A. 1931. The Meloidae of South Dakota (Coleoptera). Entomol. News 12: 50-55.

Chandler, D. S. 1976. Use of cantharidin and Meloid beetles to attract Anthicidae (Coleoptera). Pan-Pacific Entomol. 52: 179-180.

Clark, W. J., F. A. Harris, F. G. Maxwell, & E. E. Hartwig. 1972. Resistance of certain soybean cultivars to bean leaf beetle, striped blister beetle, and bollworm. J. Econ. Entomol. 65:1669-1672.

Coppock, S. 1981. Blister beetle problems in Oklahoma alfalfa. Capsules College of Vet. Med. Cooperative Extension Service Oklahoma State Univ. Stillwater, OK 194: 22.

Craven, J. D. & A. Polak. 1954. Cantharidin Poisoning. Br. Med. J. 2: 1386-1388.

Crowson, R. A. 1981. The Biology of the Coleoptera. Academic Press, New York.

Dillon, L. S. 1952. The Meloidae (Coleoptera) of Texas. Texas Agric. Exp. Stn. Tech. Bull. 1597.

Dunlap, M. J. 1983. Blister beetles: Russian roulette in alfalfa hay. Western Horseman 7:22-24.

Eickwort, G. C. 1981. Agapostemon virescens (Hymenoptera: Halictidae; Halictinae) as a larval host of Lytta (Pomphopoea) sayi (Coleoptera: Meloidae). J. Kansas Entomol. Soc. 54: 519-520.

Eickwort, G. C., R. W. Matthews, & J. Carpenter. 1981. Observations on the nesting behavior of Megachile rubi and M. texana with a discussion of the significance of soil nesting in the evolution of Megachilid bees (Hymenoptera: Megachilidae). J. Kansas Entomol. Soc. 54: 557-570.

Enns, W. R. 1956. A revision of the genera Nemognatha, Zonitis, and Pseudozonitis (Coleoptera, Meloidae) in American north of Mexico, with a proposed new genus. Univ. KS Sci. Bull. Vol 37 (17).

Erickson, E. H., W. R. Enns, & F. G. Werner. 1976. Bionomics of the bee-associated Meloidae (Coleoptera); Bee and plant hosts of some Nearctic Meloid beetles, A synopsis. Ann. Entomol. Soc. Am. 69: 959-970.

Gates, D. E. & L. L. Peters. 1962. Insects in Kansas. Kansas State Univ. Cooperative Extension Service. B-94. Manhattan, KS.

Gilbertson, G. I. & W. R. Horsfall. 1940. Blister beetles and their control. South Dakota State Univ. Agric. Exp. Stn. 340.

Gorz, H. J., F. A. Haskins, & G. R. Manglitz. 1972. Effect of coumarin and related compounds on blister beetle feeding in sweetclover. J. Econ. Entomol. 65: 1632-1635.

Hanson, C. H. & R. L. Davis. 1975. Highlights in the United States. pp.35-52. In: C.H. Hansen (ed.), Alfalfa science and technology. Agronomy Society of America, Madison, WI.

Henry, K. 1983. Blister beetles. Cooperative Extension Service, The University of Arizona, Tucson, AZ. Pub. No. 8356.

Horsfall, W. R. 1942. Control of the striped blister beetle through its gregarious habits. J. Econ. Entomol. 35: 449.

Horsfall, W. R. 1943. Biology and control of common blister beetles in Arkansas. Univ. of Arkansas Agric. Exp. Stn. Bull. 436.

Ingram, J. W. & W. A. Douglas. 1932. Notes on the life history of the striped blister beetles in southern Louisiana. J. Econ. Entomol. 25: 71.

Kalu, B. A. & G. W. Fick. 1981. Quantifying morphological development of alfalfa for studies of herbage quality. Crop Sci. 21: 267-271.

Kastens, W. H. 1984. Agriculture review. pp. 100-105. In: H. E. Priddle & M. E. Johnson (eds.), The 67th annual report and farm facts. Kansas State Board of Agric. Topeka, Kansas.

Kritsky, G. 1987. Take two cicadas and call me in the morning. Bull. Entomol. Soc. Am. 33: 139-141.

Lavigne, R. & R. E. Pfadt. 1965. Insects collected on Wyoming rangeland in connection with grasshopper-egg sampling. J. Kans. Entomol. Soc. 38: 61-66.

Linsley, E. G. & J. W. MacSwain. 1942. Bionomics of the Meloid genus Hornia. In: E.O. Essig, S.B. Freeborn, H.S. Smith (eds.) University of California Publications in Entomology. University of Calif. Press. Berkeley, CA.

Linsley, E. G. & J. W. MacSwain. 1952. Notes on some effects of parasitism upon a small population of Diadasia bituberculata (Cresson) (Hymenoptera: Anthophoridae). Pan-Pacific Entomol. 28: 131-135.

MacKay, R. J. & P. Wollenman. 1981. An outbreak of blister beetle poisoning in horses in Florida. Florida Vet. J. 10: 11-13.

MacSwain, J. W. 1956. A classification of the first instar larvae of the Meloidae (Coleoptera). Univ. California Publ. Entomol. 12.

Manson, G. F. 1948. Blister beetles. Dept. of Agric. Sci. Serv. Division of Entomol. Pub. 84.

Mathwig, J. E. 1968. Population decline of adults of *Epicauta pennsylvanica* (Coleoptera: Meloidae) during the fall of 1967. J. Kansas Entomol. Soc. 41: 544-548.

Maxwell, F. G., H. N. Lafever, & J. N. Jenkins. 1965. Blister beetles on glandless cotton. J. Econ. Entomol. 58: 792-793.

McLain, D. K. 1982. Behavioral and morphological coorelates of male dominance and courtship persistence in the blister beetle *Epicauta pennsylvanica* (Coleoptera: Meloidae). Am. Midland Nat. 107: 396-403.

Milliken, F. B. 1921. Results of work on blister beetles in Kansas. USDA Bulletin 967.

Moore, R. W. 1963. Cantharides poisoning in a horse. Southwestern Vet. 961-962.

Nickolls, L. C. & D. Teare. 1954. Poisoning by cantharidin. Br. Med. J. 2: 1384-1386.

Oehme, F.W. 1981. Blister beetles Equine killers found in horse-bound hay. Kans. Horseman pp. 6-8.

Panciera, R.J. 1972. Cantharidin (Blister beetle) poisoning. pp224-225. *In*: E.J. Catcott & J.F. Smithcors [eds.], Equine Medicine and Surgery Edition 2. American Veterinary Publications, Wheaton, Illinois.

Parker, J. R. and C. Wakeland. 1957. Grasshopper egg pods destroyed by larvae of bee flies, blister beetles, and ground beetles. USDA Tech. Bull. 1165.

Pinto, J. D. 1972. Notes on the Caviceps Group of the genus *Epicauta* with descriptions of first instar larvae. Pan-Pacific Entomol. 48: 253-260.

Pinto, J. D. 1977. Descriptions of the first instar larvae of three species of *Epicautine* blister beetles (Coleoptera: Meloidae). Pan-Pacific Entomol. 53: 135-141.

Pinto, J. D. 1980. Behavior and taxonomy of the *Epicauta maculata* Group (Coleoptera: Meloidae). University of Calif. Pub. Vol. 89.

Pinto, J. D. 1984. Cladistic and phenetic estimates of relationship among genera of eupomphine blister beetles (Coleoptera: Meloidae). Syst. Entomol. 9: 165-182.

Pinto, J. D. & R. B. Selander. 1970. The bionomics of blister beetles of the genus Meloe and a classification of the new world species. Illinois Biol. Monogr. 42. Univ. of Illinois Press, Urbana.

Ray, A. C., S. H. Tamulinas, & J. C. Reagor. 1979. High pressure liquid chromatographic determination of cantharidin, using a derivatization method in specimens from animals acutely poisoned by ingestion of blister beetles, Epicauta lemniscata. Amer. J. Vet. Res. 40: 498-504.

Ray, A. C., L. O. Post, J. M. Hurst, W. C. Edwards, & J. C. Edwards, & J. C. Reagor. 1980. Evaluation of an analytical method for the diagnosis of cantharidin toxicosis due to ingestion of blister beetles (Epicauta lemniscata) by horses and sheep. Am. J. Vet. Res. 41: 932-933.

Riegert, P. W. 1968. A history of grasshopper abundance surveys and forecasts of outbreaks in Saskatchewan. Memoirs of Entomol. Soc. of Canada No. 52.

Rich, G. A. 1984. Blister beetles. Rocky Mountain Quarter Horse. pp.198-199.

Rollins, J. B. 1985. A practitioner case report: Blister beetle poisoning in horses. Equine Practice 7:6-8.

Salama, R. B., Y. Hammouda, & I. Gassim. 1974. Isolation of cantharidin from Cyaneolytta sapphirina. J. Pharm. Pharmacol. 26: 268-269.

Schoeb, T. R., & R. J. Panciera. 1978. Blister beetle poisoning in horses. J. Amer. Vet. Med. Assoc. 173: 75-77.

Scoggins, R. D. 1981. Blister beetles. Equine Professional Topics Vet. Continuing Education Cooperative Extension Service. 7: 24-27.

Scott, H. G. 1962. Blister beetle dermatitis produced by Epicauta cinerea (Coleoptera: Meloidae). J. Econ. Entomol. 55: 145-146.

Selander, R. B. 1951. The blister beetles (Meloidae) of Utah. M.S. thesis, Univ. of Utah, Logan.

Selander, R. B. 1954. Notes on the tribe Calospastini, with description of a new subgenus and species of Calospasta. Coleopterists Bull. 8: 11-18.

Selander, R. B. 1955. The proper name for the tribe Calospastini and a correction of generic synonymy (Meloidae). Coleopterists Bull. 9: 17-19.

Selander, R. B. 1960. Restriction of the genus Lytta fabricius (Meloidae). Coleopterists Bull. 14: 80-86.

Selander, R. B. 1981. Evidence for a third type of larval prey in blister beetles (Coleoptera: Meloidae). J. Kansas Entomol. Soc. 54: 757-783.

Selander, R. B. 1982. Further studies of predation of Meloid eggs by Meloid larvae (Coleoptera). J. Kansas Entomol. Soc. 55: 427-441.

Selander, R. B. & J. M. Mathieu. 1969. Ecology, behavior, and adult anatomy of the Albida Group of the genus Epicauta (Coleoptera: Meloidae). Illin. Biol. Mono. No. 41. Univ. Illinois Press. Urbana.

Shawley, R., S. Coppock, and L. M. Rommann. 1982. Blister beetles and alfalfa. Oklahoma State Cooperative Extension Service. Stillwater.

Sierra, J. R., W. D. Woggon, & H. Schmid. 1976. Transfer of cantharidin during copulation from adult male to the female Lytta vesicatoria (Spanish flies). Experientia 32: 142-144.

Sippel, W. L. 1976. Blister beetle poisoning. Cattleman 63: 208-210.

Smit, B. 1954. The C.M.R. Beetle. Farming South Africa. Reprint No. 93.

Smith, F. C. & G. A. Dean. 1950. The eighteenth or 1948 annual insect population summary of Kansas. J. Kansas Entomol. Soc. 23: 1-16.

Snead, J. S. & J. Alcock. 1985. Aggregation formation and assortative mating in two Meloid beetles. Evolution. 39: 1123-1131.

Sutherland, C. A. M. 1983. Creature feature The blister beetles, family Meloidae. New Mexico Crop Pest Reporter. New Mexico State University Cooperative Extension Service, Las Cruces, NM. 1(8): 3-4.

Van Dyke, E. C. 1928. A reclassification of the genera of North American Meloidae (Coleoptera) and a revision of the genera and species fromerly placed in the tribe Meloini, found in America north of Mexico, together with descriptions of new species. University of California Publications in Entomology 4: 395-474.

Walter, W. G. & J. F. Cole. 1967. Isolation of cantharidin from Epicauta pestifera. J. Pharmacol. Sci. 56: 174-176.

Weatherston, J. and J. E. Percy. 1978. Venoms of Coleoptera, pp.511-554. In S. Bettini (ed.), Arthropod Venoms. Springer-Verlag, NY.

Werner, F. G. 1953. Further notes on North American Epicauta, with new synonymy (Coleoptera: Meloidae). Psyche 60: 105-114.

Werner, F. G. 1954. A review of the subgenus Gnathospasta of the genus Epicauta (Meloidae). Coleopterists Bull. 8: 25-27.

Werner, F. G. 1958. Studies in the genus Epicauta of the North American continent (Meloidae) II. The Uniforma Group. Coleopterists Bull. 12: 1-19.

Werner, F. G., W. R. Enns, & F. H. Parker. 1966. The Meloidae of Arizona. Agricultural Experiment Station. The University of AZ Tech. Bull. 175.

Willams, J. 1981. Alfalfa from the consumer standpoint. In: A. Smith (ed.) Proceedings of International Grassland Congress. Amer. Forage and Grassland Council, Lexington, KY.

Young, D. K. 1984a. Field studies of cantharidin orientation by Neopyrochroa flabellata (Coleoptera: Pyrochroidae). Great Lakes Entomol. 17: 133-135.

Young, D. K. 1984b. Field records and observations of insects associated with cantharidin. Great Lakes Entomologist 17: 195-199.

PART II:

Blister beetles (Coleoptera: Meloidae) in Kansas: Historical perspective and results of an intensive alfalfa survey

ABSTRACT Economic losses caused by blister beetles (Coleoptera: Meloidae) do not result from conventional crop damage experienced in traditional pest-crop plant systems. Blister beetles contain a potent toxin, cantharidin, which can be responsible for livestock deaths when ingested by animals in contaminated alfalfa hay. Horses are particularly sensitive to this toxin. Several sources were used to establish the historical scope of blister beetle problems in Kansas. Data from two Kansas museum-maintained insect collections indicate that at least 26 species of _Epicauta_ occur in Kansas. However, information derived solely from examination of museum or privately made collections may give the wrong species emphasis and therefore result in faulty recommendations. Results of a two-year field survey for blister beetles in northeast Kansas alfalfa provided the following information: seven species of _Epicauta_ were found, with five species identified as posing significant risk problems because of seasonal occurrence, peak abundance, or behavioral characteristics. All cuttings of alfalfa can potentially contain blister beetles, and the source of the risks change in a consistent fashion as the season progresses and the blister beetle species complex shifts. Baseline information obtained from this survey is vital to

establish unbiased risk assessments, guide future research, and should be valuable in developing practical blister beetle pest management programs.

INTRODUCTION

BLISTER BEETLES pose an unconventional insect problem of field crops. Crop defoliation, although occurring, is seldom of economic consequence. Beetles belonging to the family Meloidae contain the toxin cantharidin, a sesquiterpenoid derivative thought to have evolved as a defensive mechanism (Carrel & Eisner 1974). The common name, blister beetle, derives from the fact that a blistering reaction results when reflexive bleeding from beetle leg joints contacts skin or other sensitive tissues of mammals.

Blister beetles that are present in an alfalfa (Medicago sativa L.) field, are killed during harvest, and become incorporated into a final baled product resulting in cantharidin-contaminated hay. Livestock, especially horses, are poisoned when they eat dead, crushed beetles found in baled alfalfa hay (Oehme 1981). Toxic effects are not restricted to horses, but horses seem to be more at risk than other livestock (Oehme 1981). Postmortem clinical manifestations suggestive of cantharidin poisoning include sloughing of the digestive epithelium, nephritis, hemorrhagic cystitis, and myocardial necrosis (Schoeb & Panciera 1978).

Within the family Meloidae, members of the genus Epicauta are most commonly implicated in horse deaths.

For example, E. pennsylvanica (DeGeer), a uniform black beetle with length ranging from 6 to 12 mm, was responsible for two horse deaths in Illinois (Beasley et al. 1983). Thirty-one black and orange striped species of blister beetles have been assigned to the vittata group (Adams & Selander 1979) which includes E. lemniscata (F.), E. occidentalis (Werner), and E. vittata (F.). These 'striped species' have commonly been cited as causes in several horse deaths (Moore 1963, Bahme 1968, Panciera 1972, Schoeb & Panciera 1978, Schoeb & Panciera 1979).

Concentration of the toxin cantharidin was measured in six blister beetle species that occur in Colorado, with levels varying significantly among species and between sexes within a species; male beetles had higher levels of cantharidin than females (Capinera et al. 1985). Cantharidin is synthesized by male beetles and transferred to females during mating (Sierra et al. 1976).

The information collected in this study is being used to define risk periods that indicate high likelihood of encountering significant populations of blister beetles in alfalfa. Once risk periods are established a management program can be developed to guide growers in Kansas and surrounding states. Buyers of alfalfa hay intended for the equine market also could use the information to minimize chances of purchasing and feeding blister beetle infested hay. This report completes the first step toward developing a comprehensive blister beetle management program for Kansas alfalfa.

A two part investigation was undertaken to assess the extent and significance of blister beetles in Kansas. First, historical data (pre-1985) were assembled on species, seasonal occurrence, and abundance. Second, representative alfalfa fields were intensively sampled on a weekly basis in a three county area around Manhattan, Riley Co., in northeast Kansas. Data were collected on species occurring in alfalfa, their seasonal occurrence, and relative abundance.

METHODS AND MATERIALS

Historical Data

Numbers of Meloidae species and seasonal occurrence patterns were compiled from historical (pre-1985) sources to generate background information on blister beetles. Label data were summarized from pinned specimens maintained in two Kansas insect museums. Meloidae from the Snow and KSU museums at the University of Kansas and Kansas State University, respectively, were examined. Issues of the Kansas Insect Newsletter (KIN), a publication of the Kansas State University Cooperative Extension Service (KSU-CES) and the Kansas State Board of Agriculture (KSBA) Cooperative Economic Insect Survey Report (Bell 1984) were searched for references to blister beetles.

Collection dates of specimens maintained in the museum collections are expressed as number of blister beetles grouped into seven day intervals. Label data regarding host association were rarely available, so the museum data include specimens collected regardless of host. When described in this manner, seasonal occurrence data of museum specimens from all hosts and field survey information, representing beetles extracted solely from alfalfa, can be presented on the same Figure. The objective is to determine whether caution must be used in extrapolating from museum collections.

Alfalfa Sampling Protocol

A program was designed to intensively sample representative alfalfa fields on a weekly basis in a three county area in northeastern Kansas. Data were collected on species occurring in alfalfa, their seasonal occurrence, and abundance.

Eight alfalfa fields of at least 16 hectares were used to accommodate the sampling protocol. Three fields in Geary and Riley counties and two fields in Pottawatomie County were sampled in 1985 beginning on 8 May and continuing weekly until 11 August and every two weeks until 19 September. In 1986 three fields were sampled in Pottawatomie and Riley counties, plus two in Geary County. Sampling began 17 April and continued weekly until 17 August and then biweekly until 21 September.

A stratified sampling procedure was developed and used to sample fields for blister beetles on a weekly basis. Three linear strata were located 3.0, 15.2, and 76.2 m inside the field and parallel to the field margin. One additional parallel stratum was located in the permanent, non-cultivated border area immediately adjacent to the field in close proximity to the 3 m stratum. Five samples per stratum were collected weekly on each field visit. A sample consisted of 15 contiguous pendulum sweeps of a standard 38 cm diameter sweep net. Adjacent samples within a stratum were separated by approximately 16 m. One person completed all of the sweep sampling to minimize sampling variation.

All blister beetles collected from the sweep samples were placed into labelled Ziploc ^{R} bags before leaving the field. Bagged beetles were placed in a cooled ice chest, returned to the laboratory, and held in a freezer at -15 ^{o}C for later identification. All Meloidae were placed in vials and stored in Kahle's solution. Label information included date, field, strata, and sample number. Blister beetles were sexed and identified to species using Arnold (1976) keys and returned to the vials for storage. Pinned voucher specimens of each species are maintained in the KSU Insect Collection.

Survey data represent the combined findings of the 1985-1986 field survey seasons, unless otherwise indicated. All specimens reported in the alfalfa survey were collected using the stratified sampling method, and data are expressed as the average number of blister beetles per infested field. Because many fields were not infested, only infested fields were used in calculating the average number of beetles on a particular date. The number of infested fields and the total number of fields checked on each date were recorded. Seasonal occurrence and relative abundance over all hosts (museum data) and over a single host (alfalfa from the field survey) were compared. Influence of field strata on blister beetle densities are reported elsewhere (Part III).

RESULTS AND DISCUSSION

Historical Data

Reports from the KIN (KSU-CES, 1966-1984) and the KSBA 1984) are summarized in Figure 1. One published report (KIN No. 16, 1982) stated that alfalfa is considered to be free of blister beetles during the period from 1 May through 1 July in Kansas. The same report concluded that 1 July through 31 August was the peak period for blister beetle occurrence in alfalfa. The 1 September through 31 October period was cited as a time of lower blister beetle occurrence. These statements were altered in subsequent KIN reports (No. 11, 1984). The first line in Figure 1 represents a summary of the KIN reports. It was reported that the earliest blister beetle occurrence in Kansas alfalfa was during the first week of June (KIN No. 11, 1984). Swarms or aggregations of blister beetles were reported to occur from mid-July to mid-August (KIN No. 17, 1967 and No. 14, 1984).

KSBA reports are based on extensive state-wide surveys conducted routinely throughout the growing season by State Board of Agriculture personnel. KSBA sampling varies in frequency and intensity with the perceived applied value of the information and on availability of funds. Beginning in 1984, these weekly reports included occasional reference to seasonal occurrence and peak abundance of four blister beetle species found in alfalfa hay. Quantitative estimates, such as numbers of beetles collected per sweep, were reported occasionally.

Meloidae in Kansas Insect Museum Collections

The Snow Insect Collection and KSU Insect Collection provided museum data shown in Figures 2 through 7 as summarized from label information. Only specimens collected in Kansas are reported in these figures. The Snow collection contains pinned specimens representing 214 species of Meloidae. Sixty-eight of the 214 Meloidae species in the Snow Collection are in the genus Epicauta, and 18 of these specimens were collected in Kansas. The KSU Collection has 119 Meloidae specimens of which 55 were collected in Kansas. Fifty of the 119 Meloidae specimens belong to the genus Epicauta. Twenty two of the Epicauta species were collected in Kansas.

KIN and KSBA Newsletters reported four species of blister beetles collected from Kansas alfalfa (Figure 1). During the current study, intensive sampling revealed that at least seven species of *Epicauta* can be present at some time during the growing season in northeast Kansas alfalfa fields. Our data indicate that only five of these are found in abundance regularly.

Alfalfa field survey

E. fabricii (LeConte). This species, ranging in length from 9 to 15 mm, appears gray in color, because the black cuticle is covered with gray pubescence and is distinguished by black humeral and scutellar spots. It was the earliest occurring of all Meloidae collected from alfalfa. Specimens were first collected from alfalfa on 7 May in both years of the current study. Similarly, 2 May was the earliest that a labelled *E. fabricii* specimen was represented in either museum.

Maximum occurrence (designated as the date on which the highest count was recorded) was 5 June for the museum specimens and 17 June for the alfalfa survey. The seasonal occurrence for *E. fabricii* in both the museum collections and the alfalfa survey was 91 days (2 May through 2 August) and 70 days (9 May through 18 July), respectively. More than 50% of fields checked were continuously infested with *E. fabricii* between 12 June and 2 July. Another isolated point of field infestation occurred on 19 May when 57% of fields surveyed were infested.

Host records on museum specimen labels showed 30 specimens were collected from alfalfa, 4 from yellow sweet clover (*Melilotus officinalis*), and 2 from short-grass prairie. In two years, 501 specimens of *E. fabricii* were collected in the alfalfa field survey, the most of all Meloidae species. Although 42% of blister beetles collected from alfalfa fields during the 1985 and 1986 seasons were *E. fabricii* (Table 1), this species represented only 13% of the museum specimens. Eighty-nine specimens in the two museum collections (Figure 2) had the requisite label information to be of use in this study. *E. fabricii* occurred individually and did not form definable aggregations in alfalfa.

E. immaculata (Say). This species is relatively large in size (ranging from 12 to 20 mm) with a black cuticle densely covered with red-brown to gray pubescence with no black markings present. *E. immaculata* had the second earliest occurrence. Specimens were first collected from alfalfa on 6 June and found to occur in the museum collection by 6 May.

The numbers of specimens collected during the alfalfa survey data were relatively low both years (12 and 8 specimens for 1985 and 1986, respectively). Maximum number of E. immaculata occurred earlier (20 June) in alfalfa than their maximum abundance (July 15) indicated by the museum collections. E. immaculata was found in alfalfa from 6 June to 2 August, a 57 day interval. At most, two fields were infested in any week (28 June through 4-5 July). On the remaining dates of occurrence only one field was infested.

Host records specified on insect labels from museum collection data included 17 from alfalfa, 1 from yellow sweet clover and 3 from various unspecified species of weeds. Six of the museum specimens were reared from grasshopper egg pods.

E. immaculata was represented by 182 specimens (27% of specimens) in the museum insect collections. Only 20 specimens were collected in two years of the field survey (representing only 1.7% of all blister beetles collected (Table 1). This species was not observed in aggregations in alfalfa. This species was not found abundantly enough in northeast Kansas alfalfa to be of economic concern.

E. lemniscata (F.) and E. occidentalis Werner. These species are taxonomically very similar, and identical in size (ranging from 8 to 16 mm), but are distinguished by antennal and protibial characteristics (Arnold 1976). They are very likely the striped species referred to in Figure 1, which are brown-yellow in background color with three black stripes per elytron. The earliest occurrences of both species was 17 June.

The number of beetles collected during the 1985 alfalfa field survey indicates that these two species were rare in occurrence. Thirteen and eight specimens of *E. lemniscata* and *E. occidentalis*, respectively, were collected during the entire season. However, in 1986 they were collected more frequently using approximately the same intensity of sampling. Eighty-five specimens of *E. lemniscata* and 64 specimens of *E. occidentalis* were collected. Maximum abundance of both species occurred on 23 June. These two species have one of the longest periods of occurrence of all species observed in alfalfa (viz. 96 days, from 17 June through 21 September). These data were not available from the museum collections because of the relative absence of preserved specimens.

It was apparent that these species were observed in mixed species aggregations as reported in both the KIN and KSBA. Unfortunately, no voucher specimens of the striped blister beetles are available to confirm or refute this probable identification. Swarms were encountered on 12 July in 1985 while sampling alfalfa (2 aggregations in one field of at least 5,000 beetles each). In 1986, an aggregation of ca. 300 beetles was observed as a consequence of conducting the reported sampling procedure. Additional sampling stimulated by the discovery of these aggregations led to the discovery of other swarms. At no time was the percentage of fields infested greater than 50% for either of these two species.

No specimens of E. occidentalis and six specimens of E. lemniscata were present in the two Kansas insect museum collections. E. lemniscata and E. occidentalis were the least represented species in the museum collections (0.9 and 0%, respectively (Table 1)).

The aggregation behavior and long period of occurrence makes these somewhat uncommon species of substantial economic importance. Horse necropsies have confirmed that at least two fatal poisonings during 1987 were caused by this species (Higgins unpublished data).

E. sericans (LeConte). This species ranges from 7 to 11 mm in length, and the black cuticle is covered with gray pubescence. It is distinguished by slender, stick-like metatibial spurs, and it lacks black markings. Based on museum specimens, _E_. _sericans_ had a 116 day seasonal occurrence of 6 June to 30 September, which was the longest of any species. The occurrence of this species based on the alfalfa survey was 55 days from 28 June to 22 August. At no time did the percentage of fields infested exceed 50% of those sampled.

Museum collection data indicate that the population of _E_. _sericans_ may have two maximum occurrence dates, the second week in July and the first week in September, suggesting a bimodal abundance curve. This is probably an artifact because of the random method of specimen collection characterizing museum collections. However, the few specimens collected during the alfalfa survey tend to support this observation.

Host records specified on insect labels include 10 specimens collected from _Solidago_, 4 from _Helianthus_, 2 from _Xanthium_, 4 from _Grindelia_, and 1 from _Aster_. These data indicate that _E_. _sericans_ can be found on a number of host plants in Kansas. The broad host selectivity would account for its greater abundance in museum collections.

_E_. _sericans_ is well represented in the two insect collections (116 specimens). It composed 17% of the specimens, which met the search criteria, but it was rarely found (8 specimens or 0.7% of all blister beetles) during both years of the alfalfa field survey (Table 1).

E. pestifera Werner. This species, ranging in size from 6 to 16 mm has two distinct color morphs with black background color. The predominant morph in Kansas is covered with gray pubescence except for the base of the elytra which is black. The morph predominantly found in the southeastern US and rarely found in Kansas is covered with black pubescence marginated by gray pubescence on the edges and along the suture of the elytra.

The first occurrences of *E. pestifera* coincided on 27 June for both the alfalfa survey and the museum collections (Figure 6). The peak abundance occurred somewhat earlier in alfalfa (21 July) than the most common collection date represented in the museums (5 August). However, the third harvest of alfalfa in 5 of the 8 fields checked in 1986 occurred between 16 July through 23 July. Thus, the decrease at this time can probably be attributed to cutting date rather than an indication of bimodality in the population.

Host records from insect labels include 2 specimens collected from alfalfa, 1 from *Helianthus*, and 1 from corn/sorghum. *E. pestifera* was found more frequently in the two years of alfalfa surveying (327 specimens) than in the two museum collections (33 specimens). E. pestifera composed 4.8% of the total museum specimens and 27.6% of the total specimens collected from alfalfa in the two field seasons (Table 1). Eighty-one percent of the total E. pestifera specimens were collected in 1985.

The length of occurrence for the two sources was 27 June through 15 September (80 days) for the alfalfa survey, and 27 June through 10 October (105 days) for the museum specimens. This species occurred as scattered individuals in the sampled alfalfa fields.

E. pennsylvanica (DeGeer). This species has black background color and black pubescence with no markings and ranges in size from 6 to 12 mm. E. pennsylvanica was the species making the latest initial appearance. First specimens were collected from alfalfa on 2 August 1985 and 4 August 1986 (Figure 7). KSBA reported maximum numbers from 1 September to 21 September. The museum collections document the first specimen by 6 June and the last on 10 October, a range of 126 days.

The date of maximum occurrence derived from the museum collections was 24 August. The alfalfa survey reveals a briefer period of occurrence, 5 August through 20 September, or 46 days. Maximum abundance occurred approximately at the same time in either data set (20 through 30 August).

Host records from insect labels include 18 specimens collected from Medicago, 34 from Solidago, 10 from Aster, 11 from Grindelia, 2 from Amaranthus, 1 from Glycine max, 3 from Polygonum, 1 from Salvia, and 1 from unidentified weeds. The two insect collections house specimens occurring from 1 June through 10 October. This species was responsible for 37.4% of the seven Meloidae species of interest from the museum collections but only 13.3% of the specimens collected during the alfalfa survey.

Table 1 compares the blister beetle composition of the two Kansas insect collections (total numbers of the seven species were included) with the total number of specimens collected during the 1985 and 1986 Kansas alfalfa field survey. The blister beetles represented most numerously in the museum collections were E. pennsylvanica, followed by E. immaculata and E. sericans. Epicauta immaculata and E. sericans were found with very low frequency in the alfalfa field survey. The limited host plant information that was available on insect labels of museum specimens indicated that several of these have been collected from a variety of host plants which included alfalfa.

Meloidae found most numerously in Kansas alfalfa were *E. fabricii* followed by *E. pestifera* and *E. pennsylvanica*. Numbers of beetles found in the two Kansas collections are not representative of their frequency of occurrence in alfalfa. These data suggest baseline data derived solely from examination of museum or privately made collections might give the wrong species emphasis and therefore result in incorrect recommendations for management in alfalfa.

Seasonal occurrence data obtained from the museum collections indicate that at least five of the species can occur in Kansas outside the calendar dates documented through the alfalfa survey. The museum collections represent a broader host range and were derived over a longer time span. Because *E. lemniscata* and *E. occidentalis* were very poorly represented in both museum collections similar determinations were not possible for these species.

Figure 9 summarizes the seasonal and peak occurrence of the seven blister beetle species which were found while conducting the 1985 and 1986 alfalfa survey program in Kansas. Peak occurrence in Figure 9 is defined by any of the following 3 factors: 1. infestation per infested field greater than 5 beetles; 2. more than 50% of fields sampled on that date were infested; and 3. period when aggregations were found in the species which exhibit this behavioral characteristic.

The occurrence of blister beetles effectively coincides with the entire alfalfa production season from early May until mid-September. First harvest of alfalfa usually occurs about the third week in May and the last harvest usually occurs the first week in September. However, occurrence was greatest during cuttings two through four.

Epicauta sericans and *E. immaculata* occurred in very low numbers (6 in 1985 and 2 in 1986, 12 in 1985 and 8 in 1986, respectively). The low frequency of these species probably eliminate them from contributing significantly to the problem of cantharidin contamination of alfalfa hay in northeast Kansas. Of the remaining five species, *E. fabricii*, because of its long peak occurrence period, and *E. lemniscata* and *E. occidentalis*, because of their tendency to form aggregations, are of particular interest.

In conclusion, museum label information must be used with caution when developing data on seasonal and peak occurrences of Meloidae for crop management purposes. Intensive field studies are still needed to realistically assess risks from the blister beetle species that deserve concern. Data on host associations and important behavioral characteristics (i.e. tendency to form aggregations) unfortunately often are not included on museum labels and only can be obtained from intensive and timely field observation.

Information available as a result of the historical review and two year field survey gives more insight into blister beetle activity in Kansas alfalfa than was previously available. Several sources can be used to document species composition, seasonal occurrence, peak occurrence, and relevant behavioral traits of common alfalfa-infesting blister beetles. For instance, although it has been shown that no cutting of alfalfa in northeast Kansas is blister beetle free, the source of the risks changes in a consistent fashion as the season progresses and the complex of blister beetle species shifts. This baseline information is vital to establish unbiased risk assessments, guide future research efforts, and should be invaluable in developing a practical blister beetle pest management program.

ACKNOWLEDGMENTS

We thank Andrew Lenssen, Barb Paxson, and Tim Gibb for their help in obtaining and entering data from the museum collections. We appreciate the efforts of Marlin Rice, Alberto Broce, Derrick Blocker, and Gerald Wilde for their editorial suggestions. We would like to thank Dr. George Byers curator of the Snow Collection for allowing us to use access this resource. Ken Parker, Norm Hupe, Albert Wood, George Leonard, Vincent Borg, and Ron Strauss allowed us to survey their alfalfa fields. Contribution No. 88-34-J, Kans. Agric. Exp. Stn., Kansas State Univ., Manhattan. This research was supported in part by Hatch Project KAN00581 and Animal Health Project 4-81811.

LITERATURE CITED

Adams, C. L. & R. B. Selander. 1979. The biology of blister beetles of the Vittata Group of the genus Epicauta (Coleoptera, Meloidae). Bull. Am. Mus. Nat. Hist. 162: 137-266.

Arnold, D. C. 1976. Cantharidin toxicosis in horses. J. Am. Vet. Med. Assoc. 182: 283-284.

Bahme, A. J. 1968. Cantharides toxicosis in the equine. Southwestern Vet. 21: 147.

Beasley, V. R., G. A. Wolf, A. C. Ray, & W. C. Edwards. 1983. Cantharidin toxicosis in horses. J. Am. Vet. Med. Assoc. 182: 283-284.

Bell, K. O. 1984. Kansas cooperative economic insect survey report. Kansas State Board Agric. Summary 1984 p. 5.

Capinera, J. L., D. R. Gardner, & F. R. Stermitz. 1985. Cantharidin levels in blister beetles (Coleoptera: Meloidae) associated with alfalfa in Colorado. J. Econ. Entomol. 78: 1052-1055.

Carrel, J. E. & T. Eisner. 1974. Cantharidin: Potent feeding deterrent to insects. Science 183:755-757.

Moore, R. W. 1963. Cantharides poisoning in a horse. Vet. Med. 58: 961.

Oehme, F. W. 1981. Blister beetles equine killers found in horse-bound hay. Kansas Horseman pp. 6-8.

Panciera, R. J. 1972. Cantharidin (blister beetle) poisoning, pp.224-225. In: E. J. Catcott & J. F. Smithcors (eds.), Equine medicine and surgery 2nd edition, Am. Vet. Publ., Wheaton, Illinois.

Schoeb, T. R. & R. J. Panciera. 1978. Blister beetle poisoning in horses. J. Am. Vet. Med. Assoc. 173: 75-77.

Schoeb, T. R. & R. J. Panciera. 1979. Pathology of blister beetle (Epicauta) poisoning in horses. Vet. Pathol. 16: 18-31.

Sierra, J. R., W. D. Woggon, & H. Schmid. 1976. Transfer of cantharidin during copulation from the adult male to the female *Lytta vesicatoria* ("Spanish flies"). Experientia 32: 142-144.

Table 1. Percentage of seven Meloidae species found in two Kansas insect collections and in two years, 1985 and 1986 of the alfalfa field survey.

	Percentage of Meloidae specimens	
	museum	alfalfa
Species	collections	survey
E. fabricii (LeConte)	13.1	42.3
E. immaculata (Say)	26.7	1.7
E. lemniscata (F.)	0.9	8.3
E. sericans LeConte	17.0	0.7
E. pestifera Werner	4.8	27.6
E. pennsylvanica (DeGeer)	37.4	13.3
E. occidentalis Werner	0.0	6.1

Table 2. Meloidae of the genus Epicauta occurring in Kansas with specimens at either the Snow Collection, University of Kansas, Lawrence or at the Department of Entomology, Kansas State University.

Species	Snow Collection	KSU Collection
E. albida (Say)	X	X
E. atrata (F.)	X	X
E. callosa LeConte	X	X
E. conferta Say		X
E. covina (Say)	X	X
E. fabricii (LeConte)	X	X
E. ferruginea (Say)	X	X
E. gissleri (Horn)	X	
E. immaculata (Say)	X	X
E. lemniscata (F.)		X
E. maculata (Say)	X	X
E. marginata (F.)	X	
E. occidentalis Werner		X
E. pardalis LeConte		X
E. pennsylvanica (DeGeer)	X	X
E. pestifera Werner		X
E. pruinosa LeConte	X	
E. puncticollis (Mann.)		X
E. punctipennis Werner		X

E. *segmenta* (Say)	X	X
E. *sericans* LeConte	X	X
E. *solani* Werner	X	
E. *stuarti* LeConte	X	X
E. *trichrus* (Pallas)		X
E. *unicolor* (Kirby)	X	
E. *valida* (LeConte)	X	X

Figure 1. Summary of Meloidae occurrence reported in Kansas Insect Newsletter (1966-1984) and Kansas State Survey Report (Bell 1984).

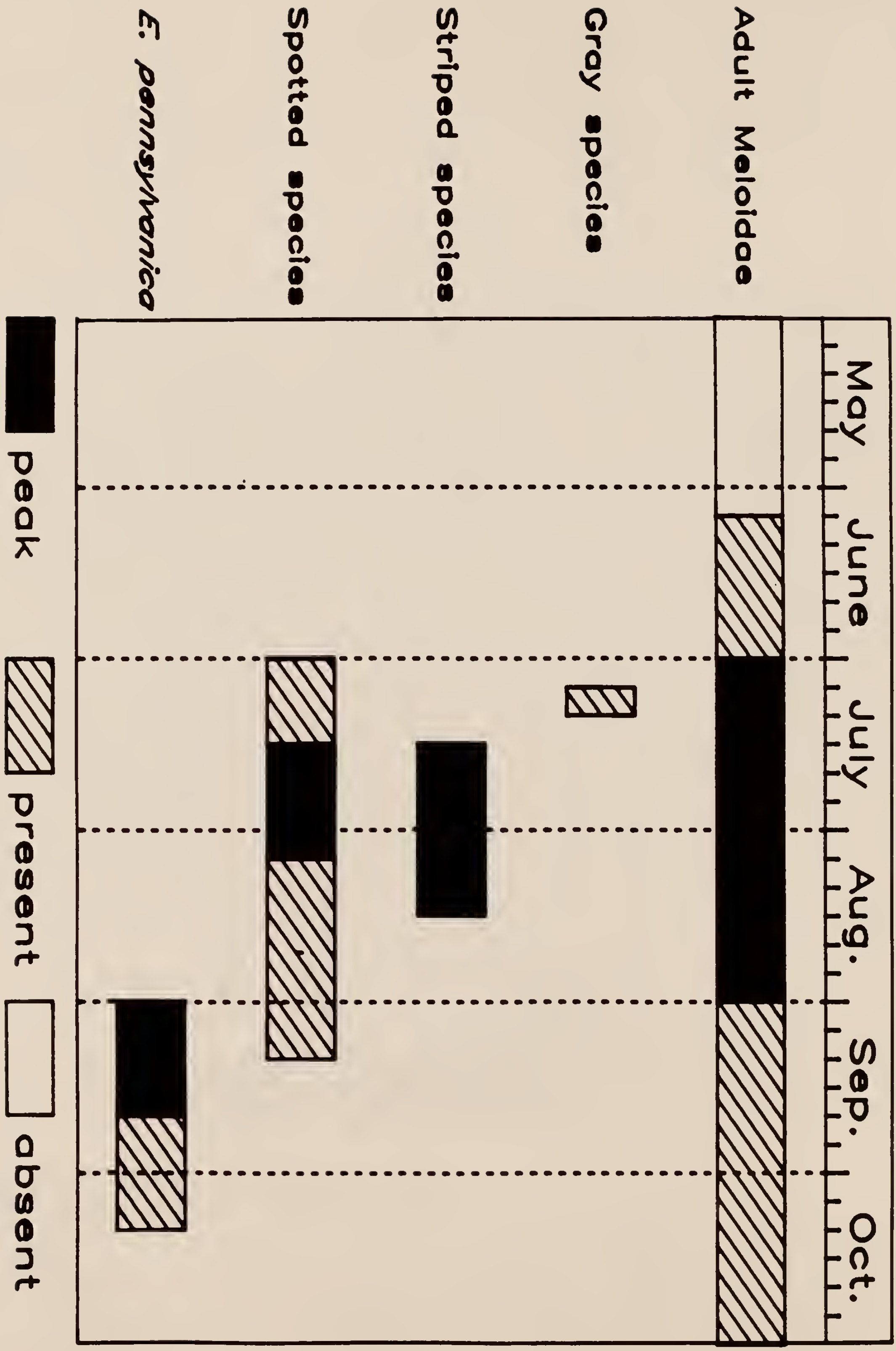

Adult Meloidae
Gray species
Striped species
Spotted species
E. pennsylvanica
May
June
July
Aug.
Sep.
Oct.
peak
present
absent

Figure 2. Seasonal occurrence of *E. fabricii* from two Kansas museum collections (n=89) and alfalfa sampling data, 1985-1986 (n=501).

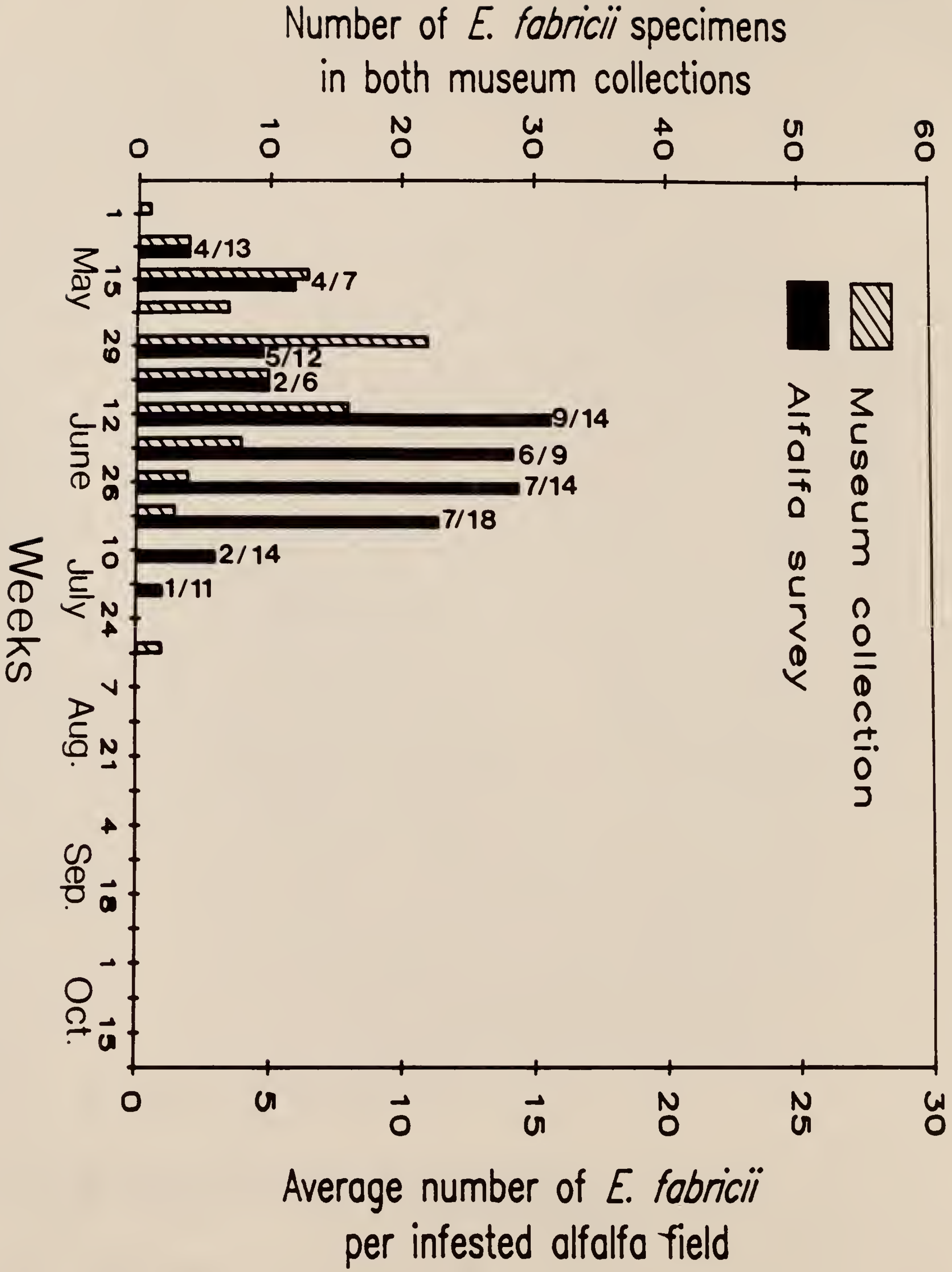
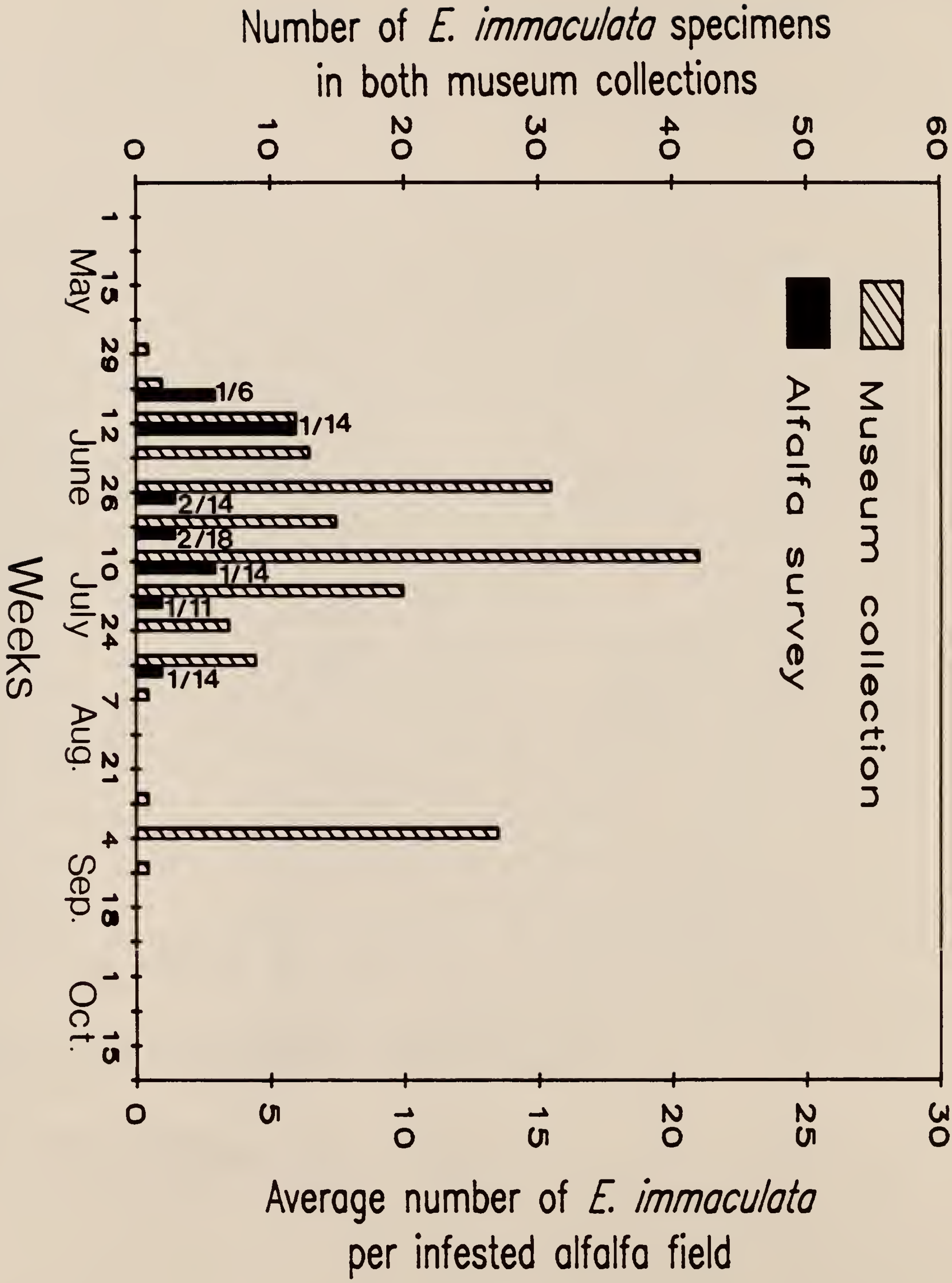

Number of E. fabricii specimens in both museum collections
Museum collection
Alfalfa survey
4/13
4/7
5/12
2/6
9/14
6/9
7/14
7/18
2/14
1/11
May
June
July
Aug.
Sep.
Oct.
Weeks
Average number of E. fabricii per infested alfalfa field

Figure 3. Seasonal occurrence of E. *immaculata* from two Kansas museum collections (n=182) and alfalfa sampling data, 1985-1986 (n=20).



Number of E. immaculata specimens in both museum collections
0
10
20
30
40
50
60
Museum collection
Alfalfa survey
1/6
1/14
2/14
2/18
1/14
1/11
1/14
1
15
May
29
12
June
26
10
July
24
7
Aug.
21
4
Sep.
18
1
Oct.
15
Weeks
0
5
10
15
20
25
30
Average number of E. immaculata per infested alfalfa field

Figure 4. Seasonal occurrence of *E. lemniscata* from two Kansas museum collections (n=6) and alfalfa survey data, 1985-1986 (n=98).

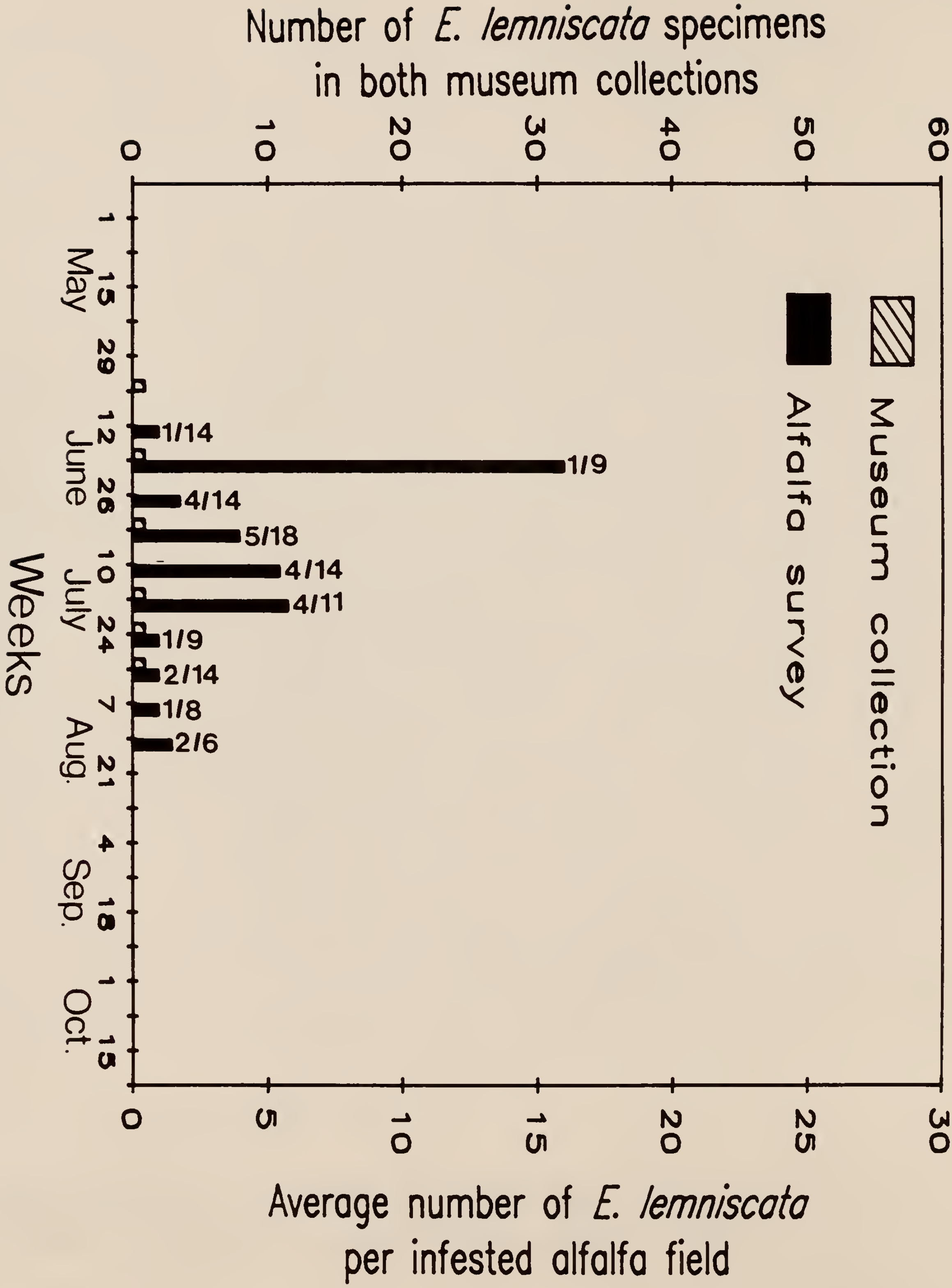

Number of E. lemniscata specimens in both museum collections
0 10 20 30 40 50 60
Museum collection
Alfalfa survey
1/14
1/9
4/14
5/18
4/14
4/11
1/9
2/14
1/8
2/6
1 15 29 12 26 10 24 7 21 4 18 1 15
May June July Aug. Sep. Oct.
Weeks
0 5 10 15 20 25 30
Average number of E. lemniscata per infested alfalfa field

Figure 5. Seasonal occurrence of _E_. _sericans_ from two Kansas museum collections (n=116) and alfalfa survey data, 1985-1986 (n=8).

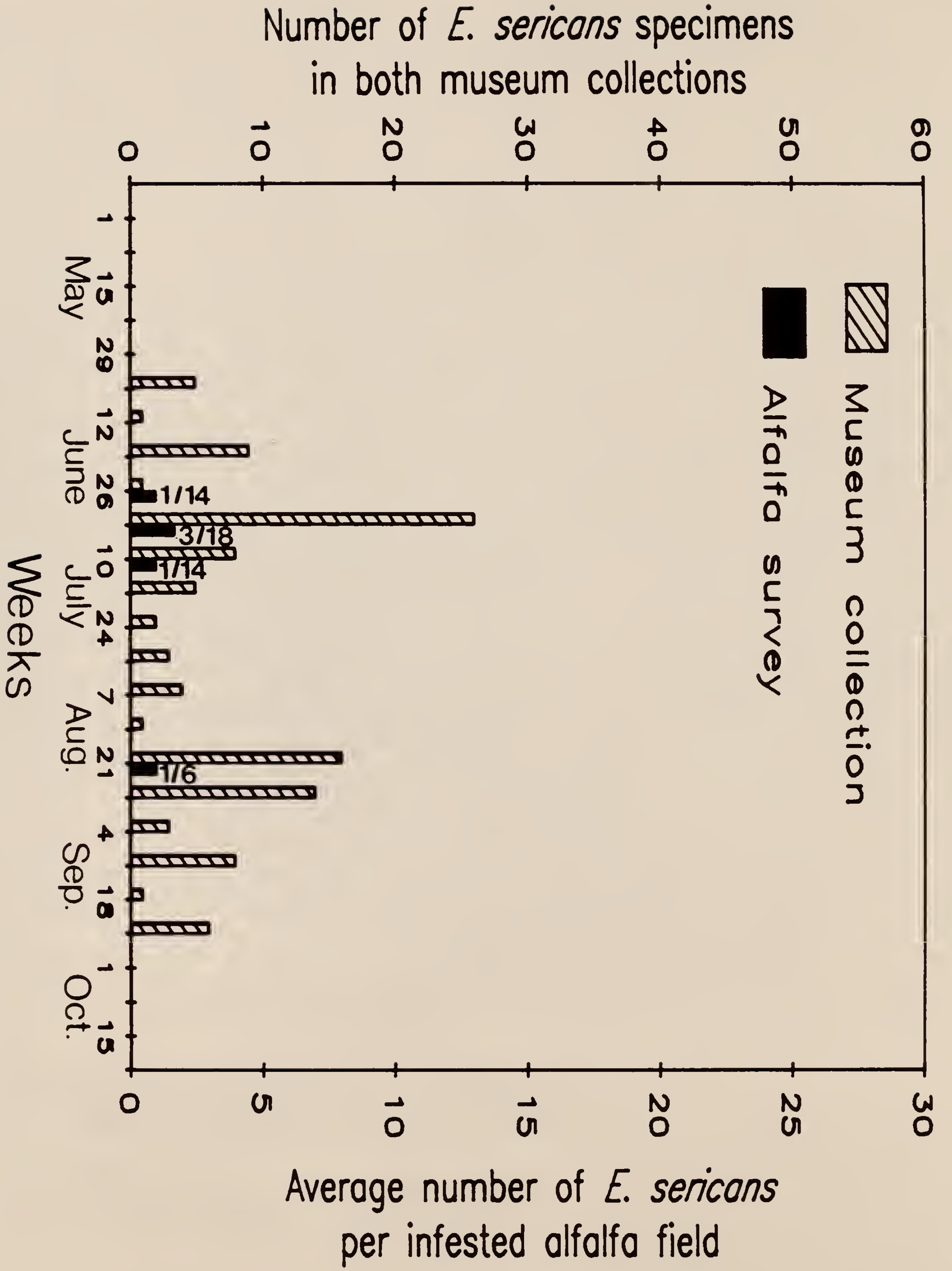

Number of E. sericans specimens
in both museum collections
0
10
20
30
40
50
60
Museum collection
Alfalfa survey
1/14
3/18
1/14
1/6
1
15
29
12
26
10
24
7
21
4
18
1
15
May
June
July
Aug.
Sep.
Oct.
Weeks
0
5
10
15
20
25
30
Average number of E. sericans
per infested alfalfa field

Figure 6. Seasonal occurrence of E. pestifera from two Kansas museum collections (n=33) and alfalfa survey data, 1985-1986 (n=327).

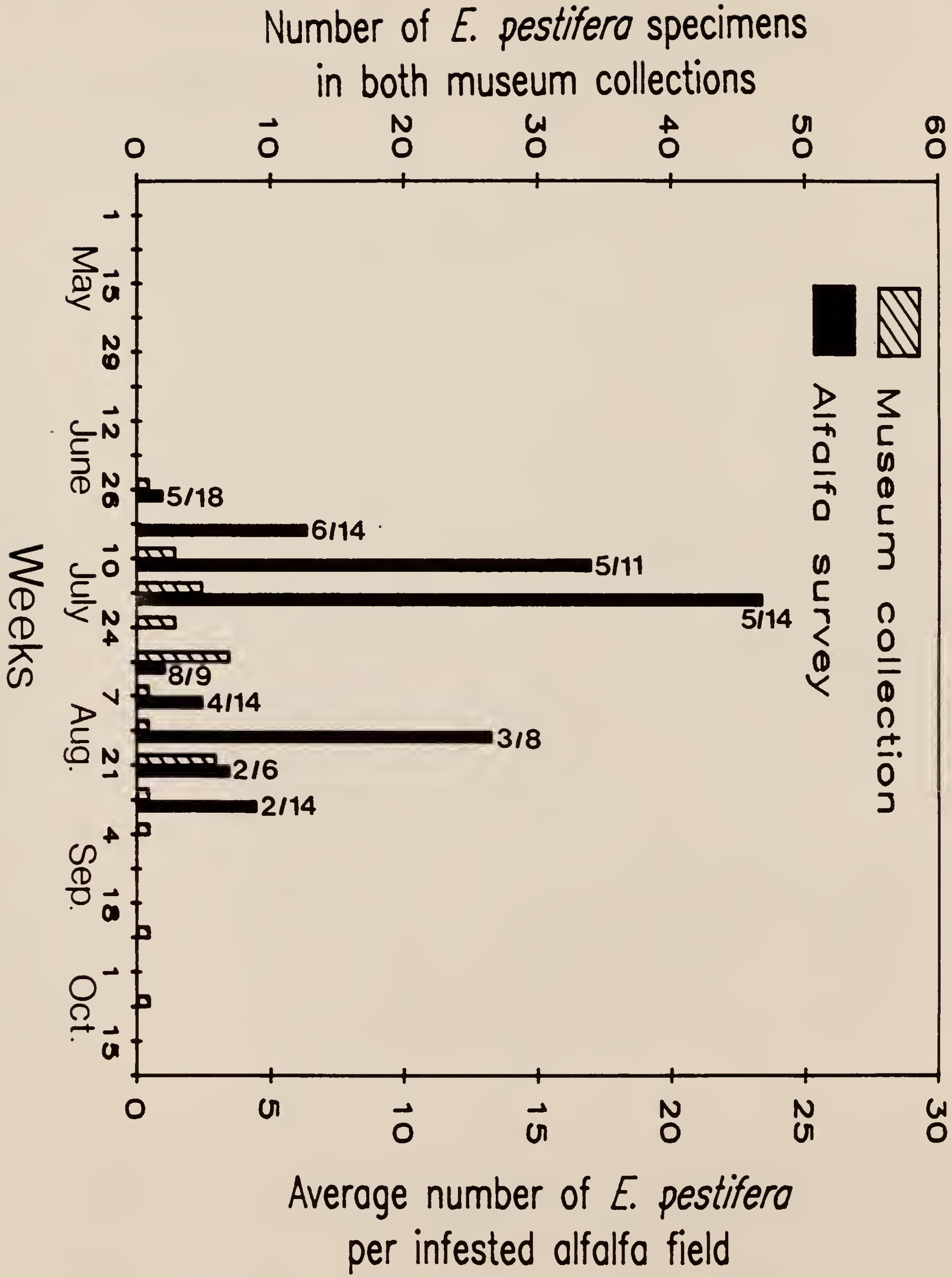

Number of E. pestifera specimens in both museum collections
Museum collection
Alfalfa survey
Weeks
May
June
July
Aug.
Sep.
Oct.
5/18
6/14
5/11
5/14
8/9
4/14
3/8
2/6
2/14
Average number of E. pestifera per infested alfalfa field

Figure 7. Seasonal occurrence of *E. pennsylvanica* from two Kansas museum collections (n=255) and alfalfa sampling data, 1985-1986 (n=157).

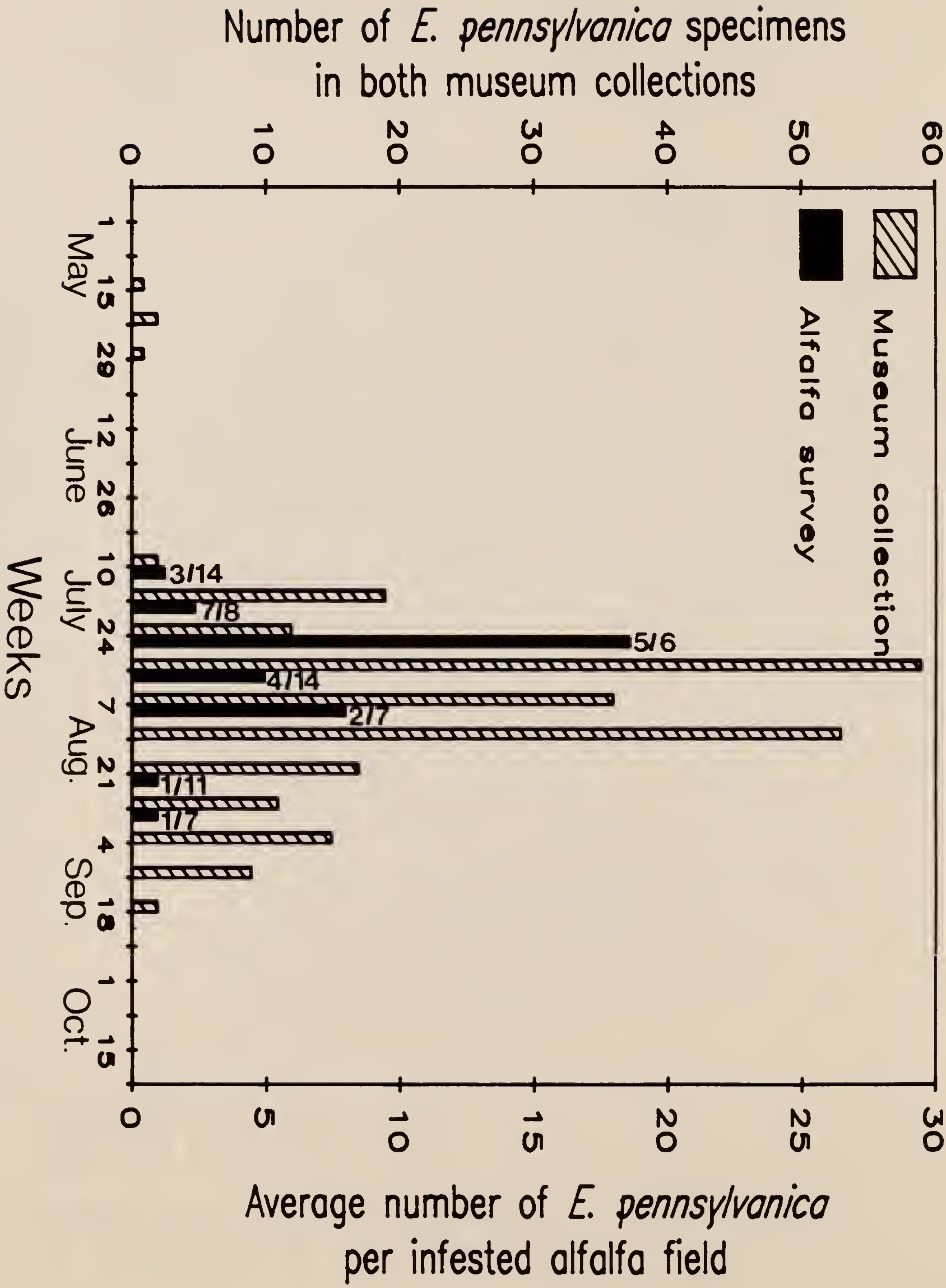
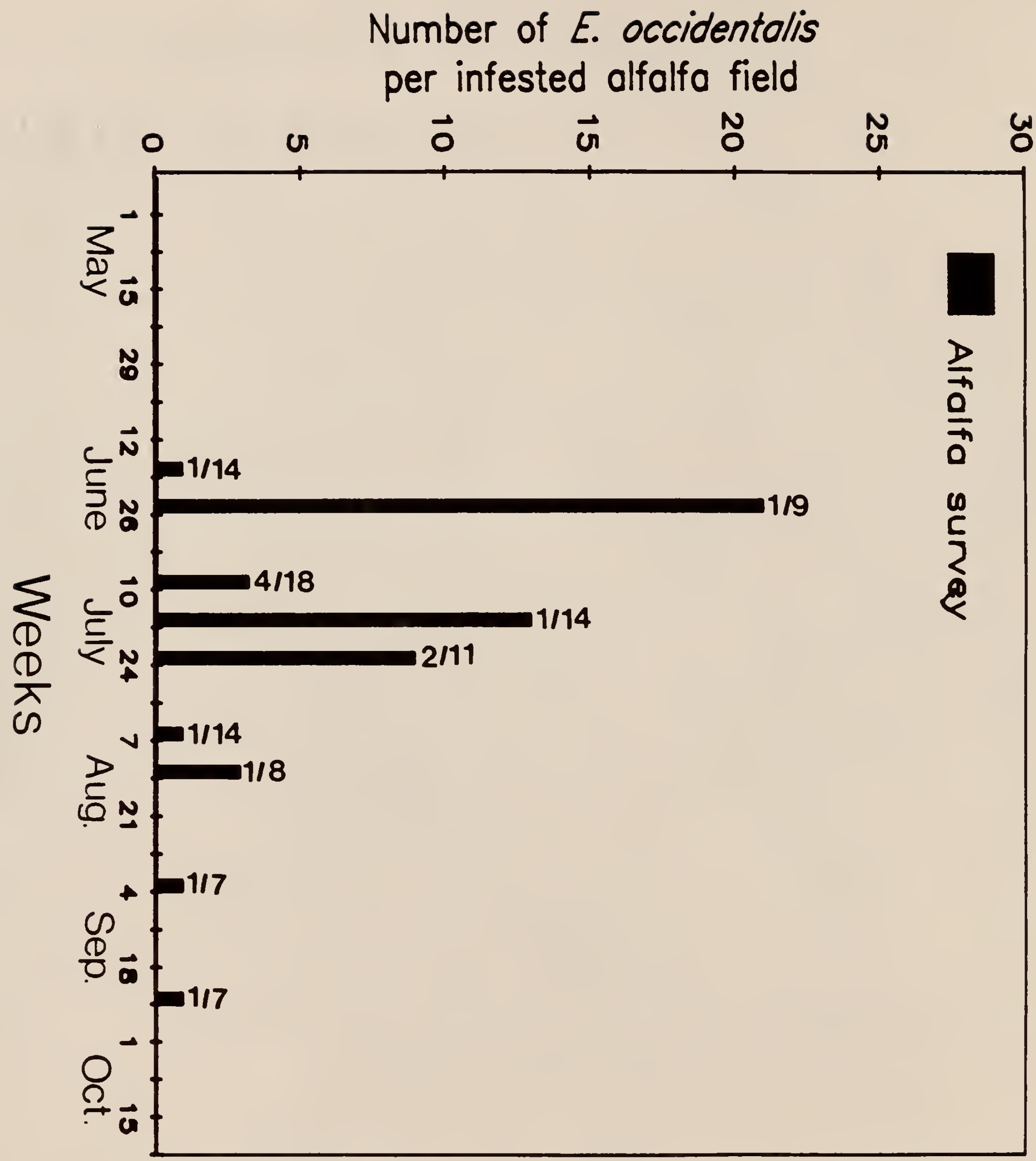
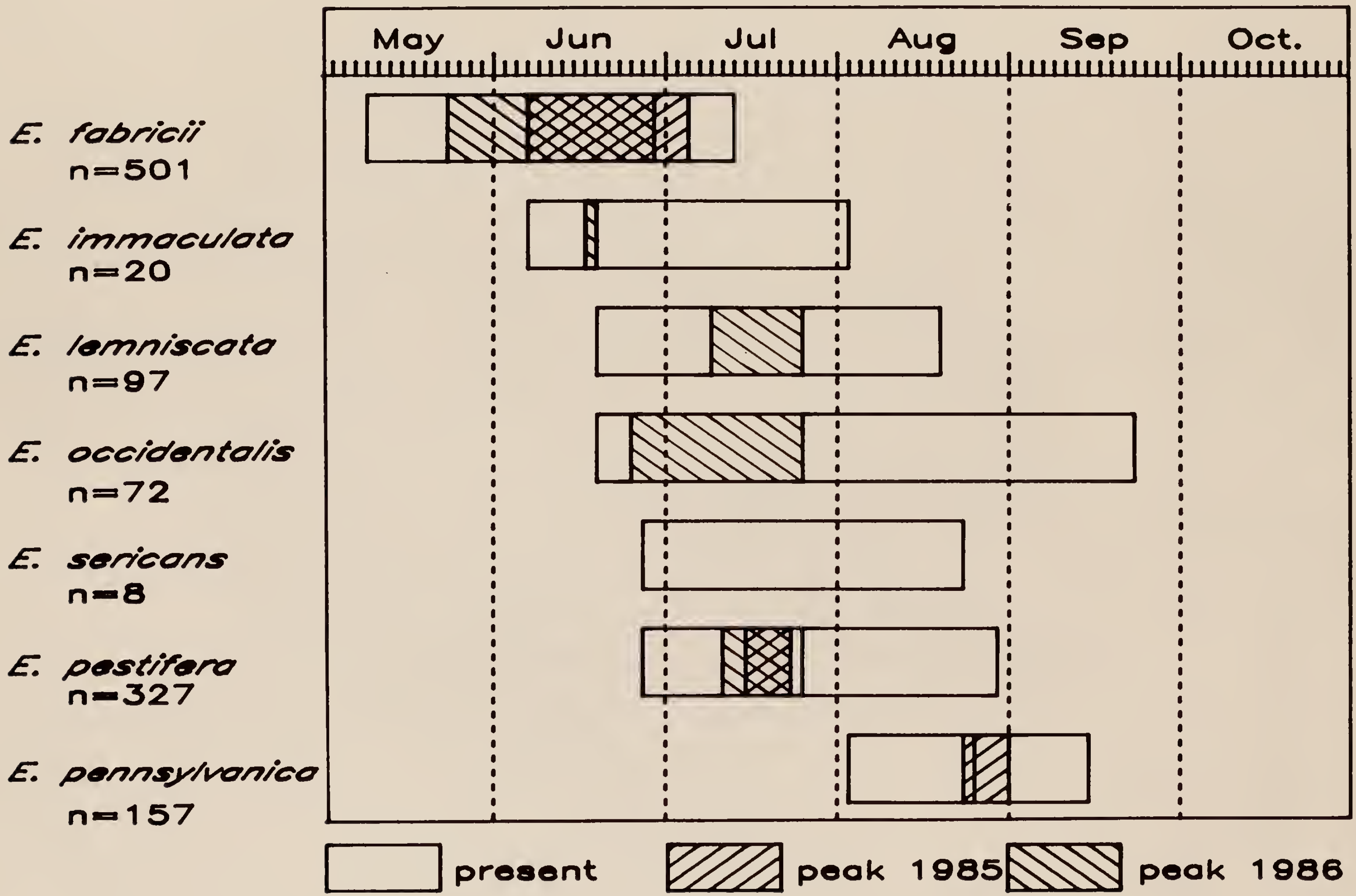

Number of E. pennsylvanica specimens
in both museum collections
0
10
20
30
40
50
60
Museum collection
Alfalfa survey
3/14
7/8
5/6
4/14
2/7
1/11
1/7
1
15
29
12
26
10
24
7
21
4
18
1
15
May
June
July
Aug.
Sep.
Oct.
Weeks
0
5
10
15
20
25
30
Average number of E. pennsylvanica
per infested alfalfa field

Figure 8. Seasonal occurrence of _E_. _occidentalis_ from alfalfa survey data, 1985-1986 (n=72).



Number of *E. occidentalis* per infested alfalfa field
0
5
10
15
20
25
30
Alfalfa survey
1/14
1/9
4/18
1/14
2/11
1/14
1/8
1/7
1/7
1
15
29
12
26
10
24
7
21
4
18
1
15
May
June
July
Aug.
Sep.
Oct.
Weeks

Figure 9. Peak and seasonal occurrence of seven Meloidae species found in Kansas alfalfa, 1985-1986.


May
Jun
Jul
Aug
Sep
Oct.
E. fabricii
n=501
E. immaculata
n=20
E. lemniscata
n=97
E. occidentalis
n=72
E. sericans
n=8
E. pestifera
n=327
E. pennsylvanica
n=157
present
peak 1985
peak 1986

Part III.

Blister beetles (Coleoptera: Meloidae) in Kansas: Influence of Seasonality, Alfalfa Phenology, and In-Field Locations

ABSTRACT Blister beetles constitute a substantial economic threat because they contain a potent toxin, cantharidin, which is responsible for livestock deaths. Horses are particularly sensitive to cantharidin, succumbing to illness and death following ingestion of contaminated alfalfa hay. Sweep net samples and visual observations were employed during a two-year survey of Kansas alfalfa. _Epicauta fabricii_ (LeConte), _E. immaculata_ (Say), _E. pestifera_ Werner, _E. occidentalis_ (Werner), _E. lemniscata_ (F.), _E. pennsylvanica_ (DeGeer), and _E. sericans_ (LeConte) were collected during the study. _E. immaculata_, _E. sericans_, and _E. occidentalis_ were found in very low numbers in the alfalfa survey, initially suggesting limited import for blister beetle management. However, _E. occidentalis_ was found with _E. lemniscata_ in mixed aggregations. These dense aggregations of beetles resulted in locally high concentrations of cantharidin, increasing its importance for management. Four of the six blister beetle species observed during the visual survey were found only on alfalfa plants. Thirty-five and five percent of _E. pennsylvanica_ and _E. lemniscata_, respectively, were found on plants other than alfalfa. Blister beetle population densities varied significantly among three field and one extra-field strata during vegetative and bud

phenological stages of cutting two and in bud stage of cutting three. Significant differences among strata were observed when blister beetles were summed over all phenological stages within cuttings two, three, and four.

Beetles belonging to the family Meloidae contain the toxin, cantharidin, a sesquiterpenoid derivative which is thought to have evolved as a defensive mechanism (Carrel & Eisner 1974). The common name, blister beetle, is derived from the blistering reaction resulting from contact of beetle hemolymph with skin or other sensitive tissues. Beetles that are present in an alfalfa field and become incorporated into hay during harvest may contain sufficient cantharidin to threaten the health of some animals. Horses are particularly sensitive and become ill with symptoms reminiscent of colic (Rollins 1985). Sufficient dosage of cantharidin-contaminated hay can result in death (Oehme 1981).

Frequently observed internal postmortem clinical manifestations suggestive of cantharidin poisoning include sloughing of the digestive epithelium, nephritis, hemorrhagic cystitis, and myocardial necrosis (Schoeb & Panciera 1978). Reduced blood levels of calcium are diagnostic of cantharidin toxicosis. Cantharidin levels in the blood, urine, or stomach contents confirm cantharidin as the cause of death. These toxic effects are not restricted to horses although they seem to be more at risk than other livestock.

In pest management situations economic

entomologists frequently are concerned with describing relationships between pest numbers and yield. Treatment thresholds derived from these relationships are made available to pest management specialists to improve decision-making. However, blister beetles cause problems which do not lend themselves to straight-forward evaluations for several reasons. First, the deleterious effect is on livestock consuming the alfalfa and therefore, crop quality rather than quantity is affected. Second, alfalfa quality deterioration is not equally important to all users, largely because equines are more sensitive than bovines to cantharidin toxicosis. The result is that some alfalfa producers could realize an economic incentive in the form of market premiums for 'quality horse hay' if they guarantee a blister beetle-free product. Yet, very little published information is available which explores the management of blister beetles in alfalfa.

Developing management guidelines for blister beetles requires characterizing the relationship between cantharidin and pest numbers in the pre-harvest situation, quantifying the beetle and toxin concentration transferred from standing crop to final baled product by various harvesting operations, describing the relationship between beetle numbers and amount of toxin that cause illness and death of livestock, and determining ways in which these risks can be alleviated (Blodgett 1987, Blodgett & Higgins 1987). Avoiding, reducing, or managing risks through a partitioning of causes and consequences is termed 'risk assessment' (Wilson & Crouch 1987, Hertz & Thomas 1983). For blister beetles, risk management factors under investigation at Kansas State University include defining the blister beetle species complex infesting alfalfa, determining their relative toxicity, host preference (weed or crop), phenological preference (host stage of development), location within the field, and documenting the transfer of cantharidin from intact blister beetles to final baled product. A previous report provided information about species composition, seasonal occurrence, and peak incidence of blister beetles in Kansas alfalfa (Blodgett & Higgins 1987).

Objectives of this study were to document additional components of risk. These included in-field location of beetles, relationship between beetle occurrence and phenological stage of the alfalfa, association with non-crop plants present in the alfalfa field, and documenting other agronomic factors which may influence beetle occurrence.

MATERIALS AND METHODS

Meloidae sampling

Eight alfalfa fields in the three county survey area were sampled weekly or biweekly. During 1985, three fields were sampled in Geary and Riley counties and two fields in Pottawatomie County. Sampling began 8 May and continued weekly until 11 August, then continued every two weeks until 19 September. In 1986, three fields were sampled in Pottawatomie and Riley counties and two fields in Geary County. Sampling began 17 April, continued weekly until 17 August, then slowed to biweekly until 21 September.

Fields chosen for sampling were a minimum of 16 ha and were oriented to accommodate the stratified sampling procedure. Three linear strata were located 3.0, 15.2, and 76.2 m into and parallel to the nearest field margin. One additional parallel stratum was located in a permanent non-cultivated border area immediately adjacent the field. Five samples per stratum were collected and the average phenological rating (Kalu & Fick 1981) of the alfalfa was determined during each field visit. A sample consisted of 15 contiguous pendulum sweeps of a standard 38 cm diameter sweep net followed by a visual observation which encompassed approximately the same area in an adjacent location. One individual completed all of the sweep sampling to minimize sampling variation. Adjacent samples within a stratum were separated by approximately 16 m. Visual observations were taken by slowly walking through the area while looking for blister beetles. Once located, beetles were observed for a brief period (2 to 3 min). Data were collected on their activity (feeding, wandering, resting, swarming), plant association, and phenological stage of the crop.

All blister beetles collected from the sweep and visual samples were placed into labelled Ziploc bags before leaving the field. Bagged beetles were placed in a cooled ice chest, returned to the laboratory, and held in a freezer at $-15^{\circ}C$ for later identification. All Meloidae then were placed in vials and stored in Kahle's solution. Label information included date, field, and sample number. Blister beetles were sexed and identified to species using Arnold (1976) then were returned to vials for storage. Voucher specimens of each species are maintained in the KSU collection.

Agronomic sampling

Phenological ratings were assigned on each visit using the method of Kalu and Fick (1981). Comparisons of blister beetle densities among field strata and among phenological stages of alfalfa were accomplished using analysis of variance (SAS Institute 1985). Mean differences in beetle densities among strata and agronomic stage were evaluated at $P < 0.05$ level of significance and separated using pair-wise t comparisons (SAS Institute 1985). Mean numbers of beetles per farm were summed across phenological stages within each cutting for each stratum and also summed across strata within cuttings for each phenological stage.

RESULTS AND DISCUSSION

Visual Observations

Seven Meloidae species: *Epicauta fabricii*, *E. immaculata*, *E. pestifera*, *E. lemniscata*, *E. occidentalis*, *E. pennsylvanica*, and *E. sericans*; were found during a two-year insect survey program of Kansas alfalfa fields (Blodgett & Higgins 1987). Twenty specimens of *E. immaculata* and eight of *E. sericans* were collected from alfalfa during the study. Two specimens of *E. immaculata* and none of *E. sericans* were observed during the visual portion of this study. Indications are that these latter two species are of lesser importance in Kansas alfalfa.

Six blister beetle species were found during the visual sampling (Table 1). These were most often found on alfalfa. *E. pennsylvanica* and *E. lemniscata* were the only beetle species observed on plants other than alfalfa 34 and 5 percent of the time, respectively. This observation agrees with reports made by other researchers experienced with these beetles (J. Carrel, Univ. Missouri, personal communication, Mathwig 1968). Presence of *Solidago* spp., *Amaranthus* spp., or Graminaceae in the alfalfa field may influence management considerations of *E. pennsylvanica*. *E. pennsylvanica* was the only species that reached peak population density after 1 August, which was during development of the fourth cutting (Blodgett & Higgins 1987). Management of blister beetles in this cutting may be somewhat less complicated than in previous harvests when more than one blister beetle species typically occur. Weed management may therfore influence the magnitude and therefore management significance of some blister beetle species.

Swarms of E. occidentalis and E. lemniscata were observed in four fields. Between 5,000 and 10,000 beetles per aggregation were documented in one field. Beetle aggregations automatically elevate the risk of poisoning by increasing the local concentration of cantharidin. As a consequence, special management considerations may be required if this hay is to be fed to cantharidin sensitive livestock.

Strata

Mean numbers of blister beetles are expressed on a per stratum basis within the alfalfa phenological stages for each of five cuttings across both years of the sampling program (Tables 2 through 6). There were three agronomic stages analyzed in cutting one, four in cutting two through four, and one in cutting five. Three of these sixteen analyses revealed significant differences in mean numbers of blister beetles per stratum. Densities of beetles were very low before the first harvest.

The vegetative and bud stages of the second cutting and the bud stage of the third cutting had significant differences in mean densities of blister beetles among strata. Stratum two (3.0 m from the field edge) had significantly higher densities of blister beetles than either stratum one (weedy border area), three (15.2 m from field edge), and four (76.2 m from field edge) during the vegetative stage of the second cutting. Significantly higher densities of blister beetles were found in the in-field strata two through four during the bud stage of the same cutting than in stratum one, the weedy-border. During the bud stage of the third cutting, stratum two had a significantly higher density of beetles than strata one, three, and four. Strata one, three, and four did not differ significantly. A similar trend was evident during the bloom and seed stages although significant differences were not confirmed. During cuttings four and five there were no significant differences in beetle densities among strata within an alfalfa phenological stage. Cutting five, like cutting one, had very low densities of beetles. No significant differences in mean numbers of blister beetles per farm among phenological stages within a cutting were noted when densities were summed over all strata (Table 7).

Mean blister beetle densities per farm among strata, summed across phenological stages within a cutting show significant differences in cuttings two, three, and four. The extra-field stratum had significantly less blister beetles than any of the in-field strata during the second cutting. In cutting three, stratum two had more than twice the number of blister beetles than any of the other strata ($P < 0.05$). Stratum three of cutting three had significantly more blister beetles than stratum one. Stratum four was not separated from stratum three or stratum one. In cutting four, strata two and three had forty times more beetles than stratum one. Stratum four could not be separated from other strata.

Collectively these data indicate that fewer blister beetles occur in weedy field borders than within alfalfa. However, this finding does not preclude the importance of field borders in managing alfalfa-inhabiting Meloidae. The border areas may serve as a refuge when the hay is harvested or may provide habitat for blister beetle larval prey.

In conclusion, the blister beetle problem in Kansas is comprised of seven species of Meloidae. All contain cantharidin and therefore pose a risk to livestock. Adult blister beetles in Kansas are more likely to be found in alfalfa rather than in the weedy vegetation bordering the field. Within an alfalfa field, blister beetles tend to occur with slightly greater frequency near the field border. Greater densities of blister beetles were encountered during cuttings 2 through 4, although cuttings 1 and 5 were infested to a lesser extent. Blister beetles do not appear to be strongly associated with a particular alfalfa phenological stage.

Acknowledgment

The authors thank Alberto Broce and Derrick Blocker for their review of this manuscript. We appreciate the efforts of Andrew Lenssen, Barb Paxson, and Denise Carlson for their assistance in field data collection. Contribution No. 88-191-J, Kans. Agric. Exp. Stn., Kansas State Univ., Manhattan. This research was supported in part by Hatch Project KAN00581 and Animal Health Project 4-81811.

Literature Cited

Arnold, D. C. 1976. Blister beetles of Oklahoma. Oklahoma State Agric. Exp. Stat. Tech. Bull. T-145.

Blodgett, S. L. 1987. Kansas blister beetles (Coleoptera: Meloidae) historical and alfalfa field survey results. M.S. thesis, Kansas State Univ., Manhattan.

Blodgett, S. L. & R. A. Higgins. 1987. Blister beetles (Coleoptera: Meloidae) in Kansas: Historical perspective and results of an intensive alfalfa survey. J Econ. Entomol. (in press).

Carrel, J. E. & T. Eisner. 1974. Cantharidin: Potent feeding deterrent to insects. Sci. 183: 755-757.

Hertz, D. B. & H. Thomas. 1983. Risk analysis and its applications. Wiley, New York.

Kalu, B. A. & G. W. Fick. 1981. Quantifying morphological development of alfalfa for studies of herbage quality. Crop Sci. 21: 267-271.

Mathwig, J. E. 1968. Population decline of adults of Epicauta pennsylvanica (Coleoptera: Meloidae) during the fall of 1967. J. Kansas Entomol. Soc. 41: 544-548.

Oehme, F. W. 1981. Blister beetles, equine killers found in horse-bound hay. Kansas Horseman pp. 6-8.

Rollins, J. B. 1985. A practitioner case report. Blister beetle poisoning in horses. Equine Practice 7:6-8.

SAS Institute. 1985. SAS user's guide: statistics. SAS Institute, Cary, N.C.

Schoeb, T. R. & R. J. Panciera. 1978. Blister beetle poisoning in horses. J. Am. Vet. Med. Assoc. 173: 75-77.

Wilson, R. & E. A. C. Crouch. 1987. Risk assessment and comparisons: An introduction. Science. 236: 267-236.

Young, D. K. 1984. Field records and observations of insects associated with cantharidin. Great Lakes Entomol. 17: 195-199.

Table 1. Visual observations of blister beetle species, activities, and crop associations, Geary, Pottawatomie, and Riley counties, Kansas, 1985 - 1986.

Species	Number of beetles	Percentage of beetles
E. fabricii		
Activity		
wandering, alfalfa	16	53
resting, alfalfa	1	3
feeding, alfalfa terminal	2	7
feeding, alfalfa bloom	3	10
other	8	27
Host		
alfalfa	30	100
E. immaculata		
Activity		
wandering, alfalfa	1	50
feeding, alfalfa bloom	1	50
Host		
alfalfa	2	100

E. pestifera		
Activity		
resting, alfalfa	2	29
feeding, alfalfa terminal	4	57
other	1	14
Host		
alfalfa	7	100
E. lemniscata		
Activity		
wandering, alfalfa	7	37
feeding, alfalfa terminal	9	47
other	3	16
Host		
alfalfa	18	95
Amaranthus sp.	1	5
E. occidentalis		
Activity		
feeding, alfalfa terminal	7	78
feeding, alfalfa bloom	1	11
other	1	11
Host		
alfalfa	9	100

E. pennsylvanica

Activity		
feeding, alfalfa	5	20
feeding, alfalfa bloom	8	32
feeding, *Solidago* spp.	6	24
resting, *Solidago* spp.	3	12
feeding, grass	1	4
Host		
alfalfa	15	58
Solidago spp.	9	34
Amaranthus spp.	1	4
Graminaceae spp.	1	4

Table 2. Mean blister beetle numbers in strata 1 through 4 by phenological stage of first cutting alfalfa, Geary, Pottawatomie, and Riley counties, Kansas, 1985 & 1986.

	Mean number of beetles per stratum[a]		
	Phenological stage		
Stratum[b]	Veg	Bud	Bloom
1	0.11a	0.00a	0.00a
2	0.17a	0.35a	4.00a
3	0.17a	0.40a	0.00a
4	0.22a	0.40a	0.00a
No. farms	9	10	2

[a] Means within columns followed by the same letters are not significantly different (P > 0.05, LSMEANS, GLM, SAS Institute 1985).

[b] Stratum 1 is in the weedy border adjacent and parallel to field edge. Strata 2, 3, and 4 are 3.0, 15.2, 76.2 m within and parallel to field edge, respectively.

Table 3. Mean blister beetle numbers in strata 1 through 4 by phenological stage of second cutting alfalfa, Geary, Pottawatomie, and Riley counties, Kansas 1985 & 1986.

	Mean number of beetles per stratum[a]			
	Phenological stage			
Stratum[b]	Veg	Bud	Bloom	Seed
1	0.18b	0.36b	0.30a	0.00a
2	2.05a	6.04a	4.50a	0.10a
3	0.86b	6.48a	4.30a	0.00a
4	0.36b	5.48a	2.20a	0.10a
No. farms	11	12	5	1

[a] Means within columns followed by the same letters are not significantly different (P > 0.05, LSMEANS, GLM, Sas Institute 1985).

[b] Stratum 1 is in the weedy border adjacent and parallel to field edge. Strata 2, 3, and 4 are 3.0, 15.2, 76.2 m within and parallel to field edge.

Table 4. Mean blister beetle numbers in strata 1 through 4 by phenological stage of third cutting alfalfa, Geary, Pottawatomie, and Riley counties, Kansas, 1985 & 1986.

	Mean number of beetles per stratum[a]			
	Phenological stage			
Stratum[b]	Veg	Bud	Bloom	Seed
1	0.90a	1.55b	0.33a	0.50a
2	1.70a	6.10a	9.55a	3.00a
3	0.85a	3.55b	5.38a	1.00a
4	1.60a	0.70b	1.28a	0.00a
No. farms	10	10	6	2

[a] Means within columns followed by the same letters are not significantly different (P > 0.05, LSMEANS, GLM, SAS Institute).

[b] Stratum 1 is in the weedy border adjacent and parallel to field edge. Strata 2, 3, and 4 are 3.0, 15.2, 76.2 m within and parallel to field edge.

Table 5. Mean blister beetle numbers in strata 1 through 4 by phenological stage of fourth cutting alfalfa, Geary, Pottawatomie, and Riley counties, 1985 & 1986.

	Mean number of beetles per stratum[a]			
	Phenological stage			
Stratum[b]	Veg	Bud	Bloom	Seed
1	0.28a	0.22a	0.00a	0.10a
2	0.94a	7.63a	0.20a	1.80a
3	0.89a	7.42a	1.00a	1.50a
4	0.22a	4.38a	0.20a	0.30a
No. farms	9	6	1	1

[a] Means within columns followed by the same letters are not significantly different (P > 0.05, LSMEANS, GLM, SAS Institute).

[b] Stratum 1 is in the weedy border adjacent and parallel to field edge. Strata 2, 3, and 4 are 3.0, 15.2, 76.2 m within and parallel to field edge.

Table 6. Mean blister beetle numbers in strata 1 through 4 by phenological stage of fifth cutting alfalfa, Geary, Pottawatomie, and Riley counties, Kansas, 1985 & 1986.

	Mean number of beetles per stratum[a]
	Phenological stage
Stratum[b]	Veg
1	0.00a
2	0.33a
3	0.33a
4	0.00a
No. farms	6

[a] Means within columns followed by the same letters are not significantly different (P > 0.05, LSMEANS, GLM, SAS Institute).

[b] Stratum 1 is in the weedy border adjacent and parallel to field edge. Strata 2, 3, and 4 are 3.0, 15.2, 76.2 m within and parallel to field edge.

Table 7. Mean blister beetle numbers per farm when partitioned by four phenological stages and five alfalfa cuttings, Geary, Pottawatomie, and Riley counties, Kansas 1985 & 1986.

Phenological Stage	Cutting[a]				
	1	2	3	4	5
Vegetative	0.67a	11.64a	5.30a	2.56a	0.67a
n[b]	9	11	10	9	6
Bud	1.20a	18.42a	12.09a	23.20a	--
n	10	12	11	5	
Bloom	4.00a	11.40a	14.29a	7.00a	--
n	2	5	7	1	
Seed	--	1.0a	4.5a	19.00a	--
n		2	2	1	

[a] Means within columns followed by the same letters are not significantly different (P > 0.05, LSMEANS, GLM, SAS Institute).

[b] n refers to the number of farms involved.

Table 8. Mean number of blister beetles per farm when partitioned by strata and alfalfa cutting, Geary, Pottawatomie, and Riley counties, Kansas, 1985 & 1986.

	Cutting[a]				
Strata[b]	1	2	3	4	5
1	0.65a	0.55b	0.05c	0.08b	0.00a
2	0.52a	4.77a	5.01a	3.33a	0.33a
3	0.23a	4.60a	2.25b	3.21a	0.33a
4	0.29a	3.85a	0.79bc	1.38ab	0.00a
No. farms	11	14	13	11	6

[a] Means within columns followed by the same letters are not significantly different (P > 0.05, LSMEANS, GLM, SAS Institute).

[b] Stratum 1 is in the weedy border adjacent and parallel to field edge. Strata 2, 3, and 4 are 3.0, 15.2, 76.2 m within and parallel to field edge.

KANSAS BLISTER BEETLES (COLEOPTERA: MELOIDAE) HISTORICAL AND ALFALFA FIELD SURVEY RESULTS

by

SUE L. BLODGETT

B.S., Syracuse University, 1974
M.S., Cornell University, 1980

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

(Entomology)

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1987

Economic damage caused by blister beetles (Coleoptera: Meloidae) is not the conventional crop destruction experienced in traditional economic pest management systems. Blister beetles contain a potent toxin, cantharidin, which is responsible for livestock deaths. Horses are particularly sensitive, succumbing to illness or death following the ingestion of contaminated alfalfa hay. Several sources were used to establish the historical scope of blister beetle problems in Kansas. Data from two local museum-maintained insect collections indicate that at least 26 species of _Epicauta_ occur in Kansas. Sweep net samples and visual observations were employed in a blister beetle survey program. The two-year field survey for blister beetles in northeast Kansas alfalfa resulted in the collection of seven Meloidae species, _Epicauta fabricii_, _E. immaculata_, _E. pestifera_, _E. lemniscata_, _E. occidentalis_, _E. pennsylvanica_, and _E. sericans_. Potentially all cuttings of alfalfa can contain cantharidin because at least one species is present during each cutting. The blister beetle species complex shifts as the season progresses. Five of these species were identified as posing significant risk to livestock because of seasonal occurrence, peak abundance, or behavioral characteristics. _E. immaculata_, _E. sericans_, and _E._

occidentalis were found in very low numbers initially suggesting limited import for blister beetle management. However, *E. occidentalis* has been found in aggregations resulting in locally high concentrations of beetles and cantharidin. This behavioral trait elevates this species to management importance although it was found only rarely in the regular field survey. Four of the six blister beetle species observed visually were found only on alfalfa plants. Thirty-five and five percent of *E. pennsylvanica* and *E. lemniscata*, respectively were found on plants other than alfalfa. Analyses of relative blister beetle densities among three field and one extra-field strata indicate that phenological stage of the alfalfa and cutting number are important factors influencing beetle distribution. Blister beetle population densities varied significantly among strata during vegetative and bud stages of cutting two and in bud and bloom stages of cutting three. Significant differences among strata were observed when blister beetles were summed over all agronomic stages in cuttings two, three, and four. Information obtained from this survey is vital to establish unbiased risk assessments, guide future research, and should be valuable in developing practical blister beetle pest management programs.