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OBSERVATIONS OF THE COTTON FLEAHOPPER IN ARKANSAS

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Abstract

Damaging populations of the cotton fleahopper, *Pseudatomoscelis seriatus*, colonized cotton in Northeast Arkansas in 2001. Although the insect has occasionally been observed during the past and is routinely listed as a pest of Arkansas cotton, it has not previously been a damaging pest of cotton in this region of Arkansas. Densities observed on cotton in 2001 were unusually high and persisted throughout the growing season. Multiple insecticide applications were required to protect the crop. Changing cultural practices that allow preferred host plants, especially cutleaf evening primrose (*Oenothera laciniata*), to remain within production fields at the seedling to squaring stage of crop development are suspected contributors to establishment of the cotton fleahopper on cotton. Others factors that may have contributed to this unusual pest problem were high population densities of the fleahopper, extreme dry weather that triggered early irrigation of cotton, and the abundance of many broadleaf weeds on field borders. This report chronicles observations made on cotton fleahopper abundance on wild and cultivated hosts throughout the 2001 crop-growing season. Implications to area-wide management and the tracking of insect population across whole farms or communities are also discussed in relation to the cotton fleahopper and its association with weed and crop hosts.

Introduction

The cotton fleahopper, *Pseudatomoscelis seriatus*, is an annual persistent pest of cotton in Oklahoma and Texas. In 2001, the cotton fleahopper colonized cotton in Northeast Arkansas and lingered as a chronic pest throughout the crop-growing season. Although the insect has occasionally been observed on cotton and various broadleaf weeds in Northeast Arkansas, it has never been considered a serious pest of cotton in this region of the state. Plant bug damage to cotton in Northeast Arkansas can be a critical aspect of production because of the limited length of the growing season and the need for optimum management of fruit set in this more determinate system of cotton production (Tugwell et al. 1976). Infestations of other plant bugs are common and often represent the most serious arthropod pests of cotton in Northeast Arkansas, especially infestations of the tarnished plant bug (*Lygus lineolaris*) and less frequently infestations of the clouded plant (*Neurocolpus nubilus*). Damaging populations of the boll weevil (*Anthonomous grandis grandis*) and the heliothine complex (*Helicoverpa zea* and *Heliothis virescens*) occur, but on an infrequent basis. To a large extent, this is a cotton production region with few arthropod pests and minimal use of insecticides.

A major portion of Arkansas' total cotton crop is located in this region of the state. The Buffalo Island area of Mississippi County is the central area of our observations. It is an area of intense row-crop agriculture. A high percentage of the cropland and the total land area are devoted to cotton production. Fields are large, and in comparison to other cotton production areas of the state, the landscape more closely resembles a monoculture than a diverse agroecosystem with multiple crops and large areas of natural vegetation.

Cotton fleahopper is not a new pest of cotton in Arkansas. Over the past 15 years, cotton fleahopper has been listed as a pest infesting cotton in some areas of Arkansas every year except 1995 (summarized from data reported in Williams 2001). Treatment level densities were recorded for some areas of the state 9 of the past 15 years, but the percent of the total acreage in the state with treatment level densities typically includes less than 1% of the ~1,000,000 acres planted. The largest acreage infested with damaging densities over the past 15 years was 5% of the total Arkansas crop in 1991. Most of this was associated with a relatively small acreage of cotton production in the Red River Bottoms of Southwest Arkansas. Damaging populations of the cotton fleahopper were routinely associated with cotton in Southwest Arkansas when large acreages of cotton were produced in that region 20 to 30 years ago. Infestations in Southeast Arkansas are less common, presumably because of a lack of the preferred overwintering host plant, woolly croton (*Croton capitatus)* (Snodgrass et al. 1984). Insect control recommendations in Arkansas lump all mirids into a single "plant bug" category (Johnson et al. 2001), and most of the focus for plant bug management is on the tarnished plant bug.

This paper examines the unusual colonization of cotton by the cotton fleahopper in the Buffalo Island area of Northeast Arkansas and explores possible relationships to weeds and changing agricultural production practices. The study included monitoring of cotton fleahopper infestations on cotton and weeds in Northeast Arkansas, a survey of woolly croton for cotton fleahopper infestations across the state of Arkansas, a review of background information in the literature, and an analysis of cotton crop loss estimates for Arkansas and surrounding states.

Methods

Infestation densities of cotton fleahopper on cotton were based on visual observations of cotton research plots on the Wildy Farm. Data reported in Figure 1 for June 20, June 27, July 4 and July 11 were summarized from data collected for an experiment with six treatments. Treatments were different initiation dates for insecticide applications. Each treatment was replicated 4 times and four 18-inch samples of cotton were visually examined in each plot. The average number of nymphs and adults reported in Figure 1 were based on 96 total samples taken across the research plots. Since insecticide application were applied to some plots in the study area and not other plots, the overall densities may underestimate densities that would be associated with untreated cotton and overestimate those that may be expected in cotton receiving insecticide treatments.

General observations about the initial detection of cotton fleahoppers in commercial cotton and the fraction of cotton acreage receiving insecticide treatments were based on conversations with agricultural consultants responsible for a majority of the cotton acreage in the local area centered on Wildy Farms. Initial densities reported were based on random samples of cotton fields with a drop cloth.

Observations of cotton fleahoppers on plants in ditches and borders of fields were based on monthly, and sometimes twice a month surveys. Sweep net and visual sampling procedures were used. Since a diversity of plants was found in the same habitat, care was taken to individually sample single or small patches of plants. A sample was often a single sweep of a 15-inch diameter sweep net across a single plant. Visual samples of the fruiting structures of various broadleaf weeds were also made on an occasional basis. Notes were recorded on the date, site and general densities of nymphs and adults found. Insects collected in the samples were placed in vials containing 95% ethanol and transported to a laboratory at the University of Arkansas for examination under magnification. Descriptions of the cotton fleahopper provided by Knight (1968) and comparisons to specimens in the University of Arkansas Arthropod Museum were the basis of insect identification. Weed scientists with the University of Arkansas Division of Agriculture assisted with the identification of some weed species.

Woolly croton was sampled along roadsides at numerous locations in Arkansas during August and September. Sampling procedures were sweep net samples of patches of plants. Reference specimens were collected and process as described above.

The scientific literature, especially that associated with early observations of the cotton fleahopper as a pest of cotton in Texas, was studied during the fall of 2001 relative to the general observations recorded during the summer of 2001. Cotton insect loss data compiled for the cotton growing years of 1979 through 2000 and available at a website maintained by Mississippi State University (Williams 2001) were used to examine historical trends in cotton fleahopper infestations in Arkansas and surrounding states. Data from the website for % of cotton acreage infested with cotton fleahopper and % of cotton acreage infested with above threshold densities of cotton fleahopper were entered on a spreadsheet, summarized and plotted across years.

Observations

Infestation of Cotton

Cotton fleahopper nymphs and adults were first detected by agricultural consultants in production fields on Wildy Farms (~ 4 miles south of Leachville in Missisippi County, Arkansas) and neighboring farms of the Buffalo Island area during the first and second weeks of June. Given the sporadic occurrence of the pest in this region and the difficulty associated with finding such small insects in the plant terminals, we were impressed at the timely diagnosis of this pest problem. The agricultural consultants were obviously carefully monitoring the plants for potential pests on a routine basis. This is evidence of the high level of management associated with cotton production in this study area.

The initial infestations seemed to be associated with fields that had not received herbicide treatments for broad-leaf weeds. With the weed management flexibility of herbicide-resistant cottons and over-the-top application of glyphosate, farmers in Northeast Arkansas and other areas are utilizing more conservation tillage approaches. One aspect of cotton in the study area was the cultural practice of planting strips of wheat within the cotton as wind breaks. Cotton behind wheat was also a common practice in this production region. Under both cultural systems, broadleaf weeds remain in the fields for several weeks after cotton emergence depending on the logistics of the management system. Cutleaf eveningprimrose (*Oenothera laciniata*) was a common plant that remained in fields for several weeks post emergence of cotton.

The crop consultants estimated that about 30% of the commercial cotton in Buffalo Island area received insecticide applications, mostly acephate, for control of the cotton fleahopper during the first or second weeks of June. Subsequent applications were common as the pest successfully colonized cotton and persisted throughout the crop-growing year. Most cotton acreage in the Buffalo Island area received at least one application for cotton fleahopper or tarnished plant bug (*Lygus lineolaris*) control during June.

Researchers began to monitor cotton fleahopper densities in research plots on the Wildy farm during the second week in June. Cotton in these plots was planted on May 8. An interesting aspect of the 2001 cotton crop on Wildy Farms was the need for irrigation of seedling cotton. Many of the fields in the study area received irrigation after planting and before the squaring stage of crop development. May and early June were unusually dry. Fields receiving irrigation would have included succulent young cotton plants and succulent weeds as compared to surrounding vegetation. Random observations of cotton fields on June 11 revealed a range of cotton development from fields with plants with 1-2 mainstem nodes to fields with 5-7 mainstem nodes. Cotton fleahopper adults were present in most fields, and nymphs were present in the research plots and several nearby fields. Densities in some fields were as high as 1 fleahopper per 3 plants. Average densities were much lower on the order of 1 fleahopper per 8-10 plants.

Figure 1 summarizes insect sampling data collected in research plots on Wildy Farms on June 20, June 25, July 4, and July 11. Above threshold densities (based on Texas recommendations of 10 to 15% of plants infested, http://insects.tamu.edu/extension/bulletins/e-5.html#n) were present on three of the four sample dates. The high number of nymphs and the continued infestation densities indicate that cotton fleahopper established on cotton and successfully reproduced. These data were summarized across all plots in the study area including plots that received insecticide treatments and plots that did not receive insecticide treatment. Untreated cotton would logically have higher densities of cotton fleahoppers than those reported in Figure 1.

Abundance on Weed Hosts

Following the initial observation of cotton fleahopper on cotton, we searched the natural vegetation surrounding production fields in the study area each month thoughout the crop growing season to follow populations of the insect on weed hosts. A central question was the source of the cotton fleahoppers that colonized the cotton. Woolly croton, the most important overwintering host of the insect (Holtzer and Sterling 1980 and Schuster et al. 1969), was not common on Wildy Farms or the general Buffalo Island area.

Table 1 reports field notes and general observations associated with the survey of weeds and natural vegetation surrounding cotton in the Buffalo Island area. It also includes records of subsequent surveys of woolly croton across Arkansas. As referenced in the table, cotton fleahoppers were found on several broadleaf weeds but high densities in June seemed to be associated most closely with cutleaf eveningprimrose, a preferred host plant. Observations later in the year were consistent with those reported by Snodgrass et al. (1984) who surveyed the host range of cotton fleahopper in the delta region of Arkansas, Louisiana, and Mississippi. Most of their samples were taken from sites further south than the Buffalo Island area, but overall trends in host utilization were similar to those we observed in 2001. Later in the year, cotton fleahopper nymphs were found on puncture vine (*Tribulus terrestris*). Cutleaf eveningprimrose appeared to the most important weed host of cotton fleahopper in the study area during June. This is consistent with the observations of Snodgrass et al. (1984). The source of overwintering insects and the source of insects that colonized cutleaf eveningprimrose are still unknown and topics of continuing interest.

An interesting observation recorded on June 14 (Table 1) was the presence of cotton fleahopper nymphs and adults on cutleaf eveningprimrose growing adjacent to cotton (squaring cotton with multiple fruiting forms) on Hood Farms near Gunnison, Mississippi and the Mississippi River. Densities of fleahoppers on the primrose were generally as high as those measured in the Arkansas study area, but they were not present in the adjacent cotton. The cotton on Hood Farms was more advanced and several weeks ahead of the cotton being sampled in Arkansas. Subsequent conversations with researchers in Mississippi indicated that cotton fleahopper was observed in early June in research plots across the state.

As the season progressed, we began to wonder about fleahopper dispersal from cotton to fall hosts, especially movement to hosts that may serve as overwintering sites. Densities of cotton fleahoppers on the vegetation surrounding cotton in the Buffalo Island area generally declined in July and August. Most of the population seemed to be resident in cotton.

A survey of woolly croton, the most important overwintering host of cotton fleahopper, was initiated in late August. Figure 1 shows the sample site for Hood Farms referenced above and 11 additional sites where cotton fleahopper nymphs and adults were found in high densities on woolly croton during August – October. In fact, every woolly croton site sampled had fleahopper adults and nymphs. Many of the sample sites were a hundred miles or more away from cotton production areas. No sample sites were found in the northern regions of Arkansas across the Ozark Plateau because no woolly croton plants were found. Samples taken along US 540 near Rudy, Arkansas confirmed that cotton fleahoppers were present on croton as far north as we could find croton patches. Densities of cotton fleahoppers (nymphs and adults) were high (10 or more per plant) in samples taken in clear-cut areas of pine forests near Hope and Monticello, Arkansas and Bastrop, Louisiana.

Background Information in the Literature

Many of the questions we raised about cotton fleahopper and its host ecology were similar to those found in the literature 70 years ago. The first reports of cotton fleahopper as a pest of cotton appeared in the 1920's. Reinhard (1926) reported that injury of cotton was first associated with cotton fleahopper in the coastal regions of Texas in 1920. Prior to this time, the insect was not known to damage cotton. Reinhard (1926) also reported a large number of host plants of the insect. Plant species listed by common name in the publication included goatweed or sageweed, horsemint, orach, ragweed, horsenettle, pigweed, wild caraway, henbit, lamb's quarters, wild geranium, evening primrose, pursley and morningglory or tie-vine. Damage to cotton by the fleahopper was very prevalent in Texas in 1924 (Hunter 1926), and the insect was reported to be damaging cotton in Georgia and South Carolina in 1924. Reinhard (1926) determined that the cotton fleahopper overwinters in the egg stage, primarily in *Croton* spp. and speculated that fall burning of the overwintering host plant would reduce numbers in cotton the following year.

The recognition of cotton fleahopper as a new pest problem and the unique ecological association between weed and crop hosts created interest in additional entomological research in the 1930's. Gaines (1933) was intrigued with the distribution of cotton fleahoppers in cotton and the association with weed host plants. He found that populations of cotton fleahopper were increased when rainfall produced rapid growth of host plants. He also observed definite periods during the year when the insect transfers from one host to another, and he reported that the insects migrate early in the season from weed fields and are disseminated in cotton. Later, during July and August, the insects leave cotton and migrate to goatweed (*C. capitatis*) fields where the greater portion of the eggs are deposited and remain overwinter. Gaines (1933) indicated that a minimum of 20 adult cotton fleahoppers per 100 sweeps is considered sufficient to cause economic damage to cotton. He also indicated that the fall fleahopper population in goatweed was an important factor in determining the number of nymphs that hatch in the spring.

An experiment station circular was produced by Texas A&M College in 1936 to educate farmers about the fleahopper problem (Thomas 1936). Thomas (1936) reported in the circular that cotton fleahopper causes considerable damage to cotton every year in Texas, that the extent of the damage varies from year-to-year and with geographic location of the crop, and that cotton on heavier soils was injured more than cotton on lighter sandy soils. He also reported that the insect has more than 50 host plants and that the most common (as listed in the publication by common name) were Croton or goatweed, horsemint, ragweed, broomweed , Parthenium, and primrose. He suggested that strip cropping may be of benefit in reducing fleahopper damage because of the definite preference of the insect for some host plants.

Gaines and Ewing (1938) conducted elaborate studies on the dispersal of cotton fleahoppers including captures of insects in traps at various distances above cotton, demonstrations of the establishment of fleahoppers in fields long distances from goatweed fields, and capture of adult fleahoppers by airplane sampling at distances 2,000 feet above the ground. They concluded that adult fleahoppers may move long distances from their spring host plants, which grow abundantly in the light-soil area, to cotton and other native spring food plants in the heavy-soil areas. Fletcher (1940) considered the ecological association of the cotton fleahopper with weed hosts and concluded that agricultural practices that increase preferred host plants have a direct impact on cotton fleahopper populations in cotton. He related increased problems with cotton fleahopper to changing habitats associated with increased cotton and corn production. He also suggested that careful monitoring of fleahopper populations on *Croton*, *Oenothera* and *Monardas* would allow entomologists to predict accurately when injury to cotton would occur. Hixon (1941) further studied the host range of the cotton fleahopper and reported that the insect feeds on as many as 84 species of plants.

Ecological information on the cotton fleahopper is scarce in the literature of the late 1940's, 1950's and 1960's probably because of the growing dependence on new organic insecticides. With the evolving interest in IPM and a renewed focus on ecological studies, entomologists again considered the unique host relations of the cotton fleahopper and its adaptation to cotton. Schuster et al. (1969) recorded several new host plants in the Rio Grande Valley and confirmed that *Croton*, *Oenothera* and *Monardas* were key to overall population growth of the insect. He further found that infestations of cotton fleahopper in the Rio Grande valley were associated with early migration from wild host plants in northeastern Mexico. The timing of crop susceptibility was not consistent with the local production on weed host plants. Rainfall and its direct impact on the prevalence of preferred host plants was identified as an important factor in overall population growth of the insect in northeastern Mexico. Schuster et al. (1969) speculated that the adaptation of cotton fleahopper on cotton and the initial appearance of cotton fleahopper as a pest in 1920 was the result of plant community changes on rangelands in response to increased grazing (i.e. increased abundance of *Croto*n).

Sterling and students at Texas A&M University studied the cotton fleahopper, its association with weed hosts, and its pest status on cotton for more than two decades. Numerous papers chronicle this impressive research effort in the 1970's and 1980's. Gaylor and Sterling (1976) determined that mortality and development rates of the cotton fleahopper were affected by the species and maturity of host plants. Survival and development were higher on flowering plants than on plants in a preflowering growth stage. Almond et al. (1977) demonstrated that lowering of the adult cotton fleahopper populations in the fall by insecticide applications reduced the number of nymphs that emerged the following spring. Holtzer and Sterling (1980) reported that horsemint, *Monarda punctata*, accounted for a high proportion of eggs early in the season. After July, all fleahopper eggs were found on *C. capitatus*.

Snodgrass et al. (1984) conducted the most detailed study of cotton fleahopper in the Midsouth. They studied 15 locations in the delta of Arkansas, Louisiana and Mississippi from September 1981 to October 1982. Cotton fleahoppers were found on 36 plant species, four were considered new host plant records. During May the preferred host was showy evening-primrose, *Oenothera speciaosa*. During June and July, the preferred host plant was cutleaf evening-primrose, *O. laciniata*. Dispersal to cotton was from populations produced on both species of primrose, but densities were too low to produce economically important populations. The main host plant during the late summer and fall was woolly croton, *C. capitatus*. Snodgrass et al (1984) suggested that the absence of this preferred overwintering host plant could explain the small population densities found in the delta.

Berrwinkle and Marshall (1999) recently demonstrated that fleahoppers were attracted to volatiles from false ragweed (*Parthenium hysterophorus*), croton (*C. capitatus*) and horsemint (*M. punctata*). They suggested that this behavioral response may be exploited as a new attractant-based biorational management technique.

Analysis of Crop Loss Data

All information on cotton fleahopper infestations of cotton reported by Williams (2001) for the crop production years 1979-2000 were summarized and studied relative to corresponding estimates recorded for Arkansas. Final data summaries were based on estimates of percent of total acreage infested by cotton fleahopper and percent of total acreage with densities of cotton fleahopper above treatment threshold during the crop years 1986 - 2000. Information on estimated percent crop loss, estimated number of insecticide applications, estimated cost of insecticide application, etc. were not included, and infestation acreages were not available for the crop years 1979 – 1985.

Estimates for the 2000 cotton crop indicated that 41% of the total U.S. cotton crop was infested with cotton fleahopper and that 7% of the crop was infested at treatment level densities (Figure 3). All cotton growing states except California, Florida, Tennessee and Virginia reported infestations of cotton fleahopper. Densities above treatment thresholds were reported for some areas of Alabama, Arizona, Kansas, Louisiana, Missouri, Oklahoma, and Texas in 2000. Texas, Oklahoma, and Louisiana accounted for 86%, 8% and 2% of the area with above threshold densities, respectively.

Infestations of Arkansas cotton by the cotton fleahopper are typically less than the average infestation for the entire U.S. (Figure 3). The temporal patterns of infestation for Arkansas and the U.S. follow similar trends since 1986, but above threshold densities were recorded for Arkansas only 9 of the 15 years. The percent of total crop area infested in Arkansas ranged from 0 in 1995 to a high of 51% of the acreage in 1986 (Figure 4). The percent of total crop area infested with above threshold densities ranged from 0 in 6 of the 15 years to 5% in 1991 (Figure 5). Estimates for 1988 and 1994 indicated that ~4% of the Arkansas acreage had threshold densities of cotton fleahopper. Estimates for all other years were 1% or less. Estimates for U.S. cotton indicate the highest infestation was 69% of the crop in 1980 and the lowest infestation was 21% of the crop in 1995. Interestingly, this is the same year that Arkansas reported no infestation.

Figure 4 compares the infestation estimates for Arkansas to those for the surrounding states of Louisiana, Texas, Oklahoma, Missouri, Tennessee and Mississippi for the crop growing years 1986 – 2000. Louisiana, Texas and Oklahoma all report above threshold densities of cotton fleahopper every year (Figure 5). The percentage of cotton acreage infested with cotton fleahopper ranged from 15 to 96% of the acreage in Louisiana, from 27 to 97% of the acreage in Texas, and from 72 to 100% of the acreage in Oklahoma. Oklahoma estimates indicated 100% infestations in 13 of the 15 years reported. Temporal trends in infestation indicated that fleahoppers have become less common in Louisiana since 1992 (Figure 4). Trends for Oklahoma and Texas show year-to-year variability but no indication of declining infestations. Above threshold densities tend to be higher for Oklahoma and Texas during the last four years as compared to the early 1990's.

Over the past 15 years, infestations in Missouri are less common than those in Arkansas (Figure 4). The highest percent of acreage infested was 50% of the crop in 1988. This was the second highest year of infestation reported for Arkansas when 37% of the crop was infested. Above threshold densities were reported for Missouri for the 1987, 1998, 1999, and 2000 crops. Arkansas did not report above threshold densities in 1998, 1999, and 2000.

Tennessee cotton has not been infested with measurable densities of cotton fleahopper (Figure 4). Above threshold densities were not reported for any area of Tennessee during the 15 year period. Small infestations (l% of the crop or less and smaller than that observable with the resolution of Figure 4 were reported for 1986 and 1987.

The levels of infestations reported for Mississippi (Figure 4) are more similar to those of Arkansas than those of the other surrounding states. This is logical given the adjacent nature of large cotton growing regions in both states. A few differences in infestation trends are evident in the data. Mississippi shows a declining trend in cotton fleahopper infestations similar to the trend noted earlier for Louisiana (Figures 4 and 5), but the decline begins much earlier than the Louisiana trend. Cotton fleahoppers were more of problem for Mississippi than Arkansas during the late 1980's, but areas infested in the 1990's were generally lower for Mississippi. An exception is 1997 when Mississippi reported that ~3% of the acreage had above treatment densities. Arkansas reported no areas with above treatment densities in 1997.

Conclusions and Relevance to Area-Wide Management

Reasons for the unusually high densities of cotton fleahopper in cotton on Buffalo Island in 2001 are still largely unknown, but the changing agricultural practices that allowed cutleaf eveningprimrose to remain in and near cotton fields at the pre-squaring stage of crop development appear to be important contributors to fleahopper establishment on cotton. Another contributing factor may have been the need for irrigation of seedling cotton. Once the cotton and weeds within cotton fields were irrigated, they may have been succulent, attractive plants for fleahopper oviposition and reproduction. The fleahopper definitely exhibits a preference for different oviposition hosts (Holtzer and Sterling 1980, Beerwinkle and Marshall 1999). The presence of fields of attractive host plants could have influenced the establishment on cotton.

The source of the overwintering population in Northeast Arkansas remains somewhat of a puzzle. Woolly croton was found on the levee surrounding Buffalo Island (~10 miles from the study area) and large patches of woolly croton were common near Jonesboro (~25 to 30 miles from the study area). It was not found in measurable patches on the Wildy Farm or the central Buffalo Island area. Perhaps, we simply did not find existing patches. Perhaps, immigrant insects produced on overwintering hosts outside the local area colonized the area. The earlier research by Gaines and Ewing (1938) and Schuster et al. (1969) would indicate that this is a possibility.

The close association of cotton fleahopper with plants in the *Croton*, *Monarda*, and *Oenothera* genera and the predictable sequence of movement from overwintering host to spring weeds to cotton to fall overwintering hosts make this an intriguing model of insect host selection over spatial scales larger than individual fields. It could be a model system to study area-wide management and habitat manipulation impacts on a polyphagous pest species, especially as it relates to patches of preferred host plants. The idea of predicting cotton fleahopper population growth on weed hosts and using this information in a management mode was advocated in the earliest studies on ecology of the pest (Reinhard 1926, Gaines 1933, Fletcher 1940). Evolving spatial management systems should move these concepts toward actual production environments. We need more information about the source of colonists and dispersal of colonizing insects across the study area. We noted variability in the initial densities of cotton fleahopper on cotton across Wildy Farms, but we did not associate this variability with abundance or proximity to preferred host plants.

The estimates of infestation densities clearly indicate that populations of cotton fleahopper are higher south (Louisiana and Texas) and west (Oklahoma and Texas) of our Arkansas study area. Infestations in Missouri and Tennessee are rare and probably similar to those of Northeast Arkansas. Given the predictable presence of cotton fleahopper on woolly croton across the state of Arkansas, cotton seems to be an incidental host plant of the insect…we just happen to grow cotton in a sea of cotton fleahoppers feeding on other host plants. Are the higher densities in Louisiana, Texas and Oklahoma explained simply by the abundance of woolly croton? If so, this further accentuates the need for more information on host selection and dispersal of this and other polyphagous pests. It also stimulates interesting questions about long-range movement and reestablishment of pest species (Gaines and Ewing 1938 and Schuster et al.1969). Perhaps the cotton fleahopper would be more appropriately named the "croton fleahopper". Information on the spatial distributions of croton and cutleaf eveningprimrose would assist our understanding of cotton fleahoppers on the local scale of Buffalo Island. In organized studies across the Midsouth it could be a useful model to understand long-range movement and colonization of crops by mobile pest species.

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Table 1. Observations of cotton fleahoppers on weeds and crops in Arkansas during 2001.

Date	Observation
6/11/01	Wildy Farms, Mississippi County, Arkansas -- Fleahopper adults and nymphs found on 5-7 node cotton (~1 per 10 plants). Adult fleahoppers (low densities ~1 per 20 sweeps or 20 plants) found on lambsquarter (*Chenopodium album*), giant ragweed (*Ambrosia trifida*), Palmer amaranth (*Amaranthus palmeri*), horseweed (*Erigeron canadensis*), and wheat (*Triticum aestivum*) growing on cotton field borders. High densities (10's to 100's per plant) of fleahopper adults and nymphs found on cutleaf eveningprimrose (*Oenothera laciniata*) within cotton fields and on ditches near field borders.
6/14/01	Hood Farms, Gunnison, Bolivar County, Mississippi -- Fleahopper adults and nymphs found in high densities (~10 to 20 per 25 sweeps) on rare patches of cutleaf eveningprimrose located adjacent to cotton. Fleahoppers were not found in adjacent cotton. Cotton was in the third to fourth week of squaring.
7/9/01	Field borders and ditches, Wildy Farms, Mississippi County, Arkansas -- Fleahopper nymphs and adults found on puncture vine (*Tribulus terrestris*) and cutleaf eveningprimrose. A few isolated adults observed on seed heads of smooth pigweed (*Amaranthus hybridus*) and Palmer amaranth (~1 per 20 plants).
7/31/01	Field borders and ditches, Wildy Farms, Mississippi County, Arkansas -- Density of cutleaf eveningprimrose dramatically reduced over that observed for earlier sample dates. A few fleahopper nymphs and adults (~2-3 per plant) found on puncture vine and plant refuge near old patches of eveningprimrose. An occasional adult was found on smooth pigweed, Palmer amaranth, and horseweed (~1 per 20 plants).
8/01/01	Cotton research plots, Fayetteville, Washington County, Arkansas -- Found two fleahopper adults in cotton terminals (very isolated observations, subsequent sweep net samples indicated less than one fleahopper per 100 sweeps).
8/29/01	US 71 Roadside, Waldron, Scott County, Arkansas -- High densities of fleahopper adults and nymphs (10 or more per sweep of individual plant) found on woolly croton (*Croton capitatus*).
	Over-grazed pasture, Malta, Bowie County, Texas -- High densities of fleahopper adults and nymphs found on woolly croton.
8/30/01	Logging area near pine clear cut adjacent to Southeast Research and Extension Center, Hope, Hempstead County, Arkansas -- High densities of fleahopper adults and nymphs found on woolly croton.
8/31/01	Ditches and field borders, Wildy Farms, Mississippi County, Arkansas -- A few fleahopper adults and nymphs found on puncture vine and dead plant refuge near previous sample sites. An occasional adult was observed on pigweed.
9/14/01	US 65 Roadside, Pine Bluff, Jefferson County, Arkansas -- High densities of fleahopper adults and nymphs found on woolly croton.
	US 425 Roadside, north of Monticello, Drew County, Arkansas -- High densities of fleahopper adults and nymphs found on woolly croton adjacent to pasture.
	Clear cut area, south of Bastrop, Morehouse Parish, Louisiana -- High densities of fleahopper adults and nymphs found on woolly croton.
9/20/01	Ditches and field borders, Wildy Farms, Mississippi County, Arkansas -- A few fleahopper adults and nymphs found on isolated patches of puncture vine.
	Levee for Buffalo Island, Mississippi County, Arkansas -- High densities of fleahopper adults and nymphs found on woolly croton growing along the levee for Buffalo Island near Highway 77.
	US 49 Roadside, Jonesboro, Craighead County, Arkansas – Fleahopper adults and nymphs found on woolly croton on roadside.
9/28/01	US 540 Roadside, Rudy, Crawford County, Arkansas -- High densities of fleahopper adults and nymphs found on woolly croton on roadside.
	US 540 Roadside, Rudy, Crawford County, Arkansas -- Fleahopper adults and nymphs found on unidentified broadleaf plant. Plant is prostrate growing and is suspected to a member of the spurge family (Euphorbiaceae). Additional confirmation is needed.
10/6/01	Pasture in Arkansas River Bottom, Crawford County, Arkansas -- Fleahopper adults and nymphs found on woolly croton.

* Estimates of cotton fleahoppers densities were provided for some samples. These are only general (subjective) estimates based on field notes. Readers should not interpret these data in a quantitative manner. They are provided in response to reviewer comments and are intended to help categorize major difference in fleahopper abundance

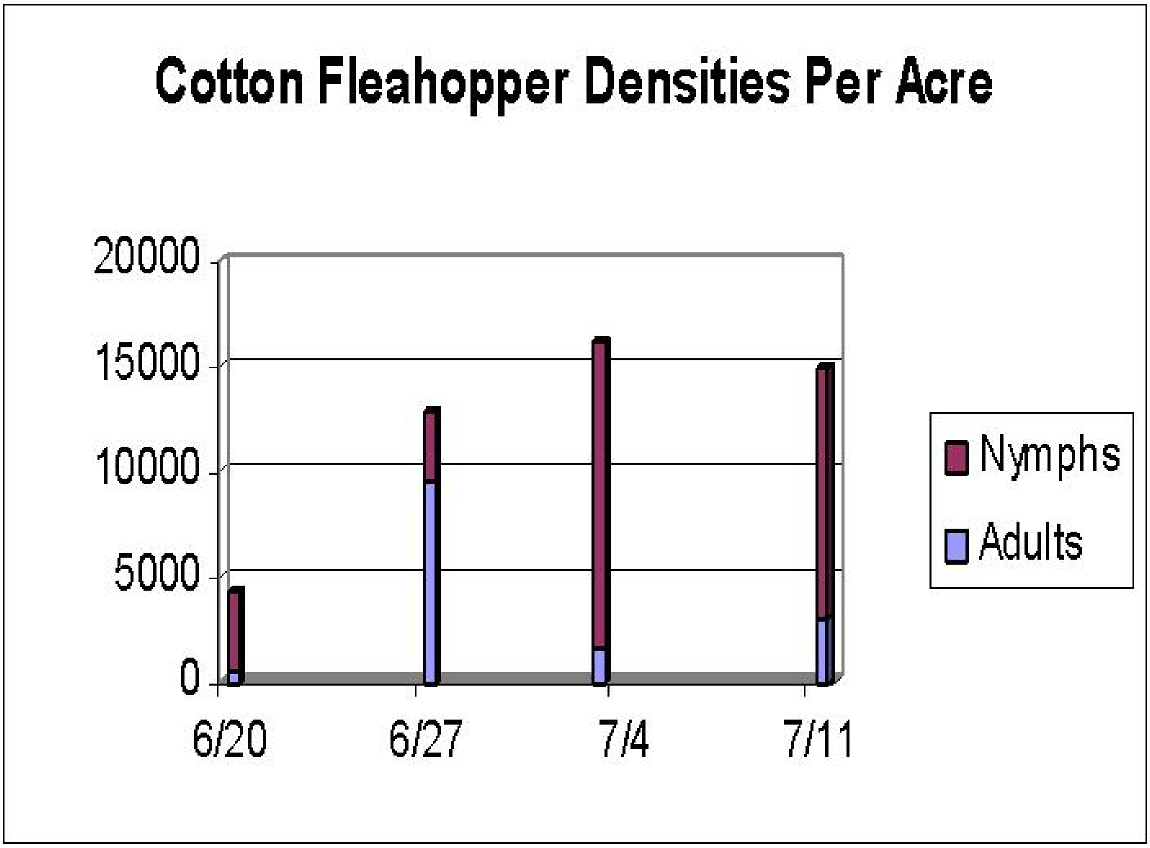

Figure 1. Cotton fleahopper densities in cotton research plots, Mississippi County, Arkansas, 2001.

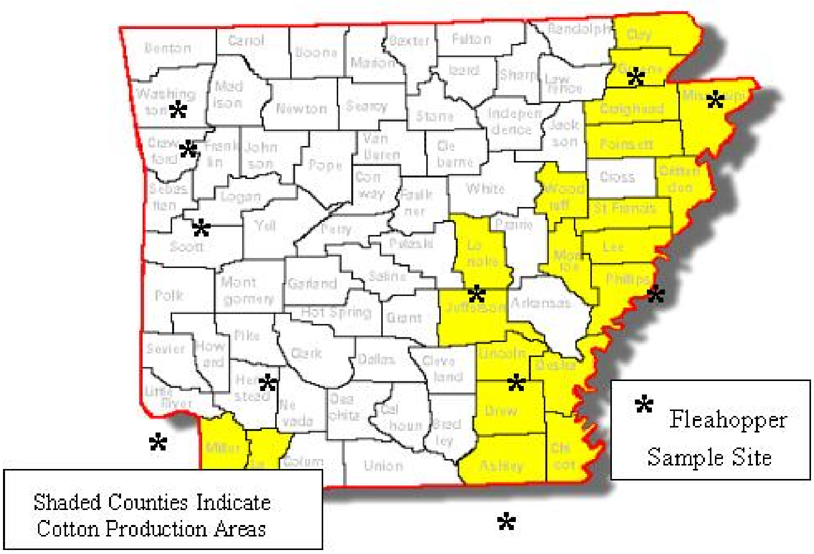

Figure 2. Sample sites (predominantly woolly croton) with cotton fleahopper nymphs and adults.

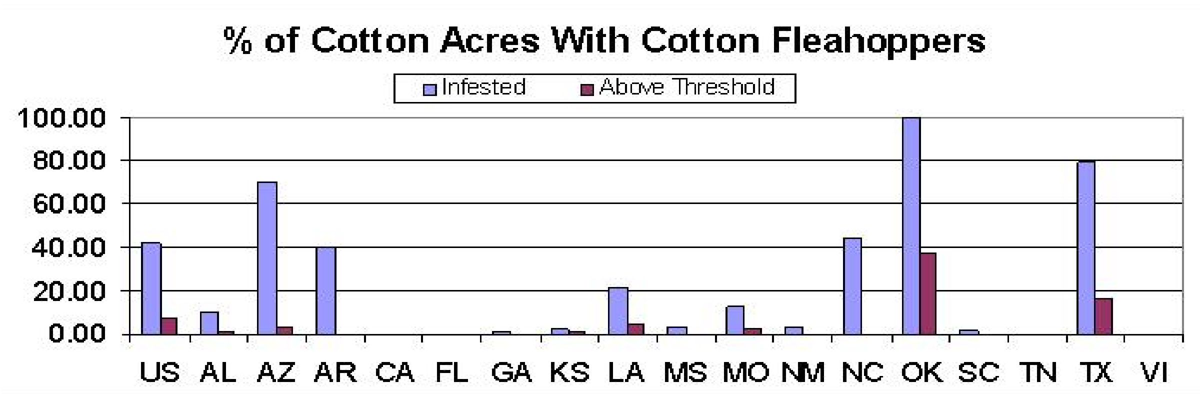

Figure 3. Infestations of cotton fleahoppers in U.S. cotton, 2000.

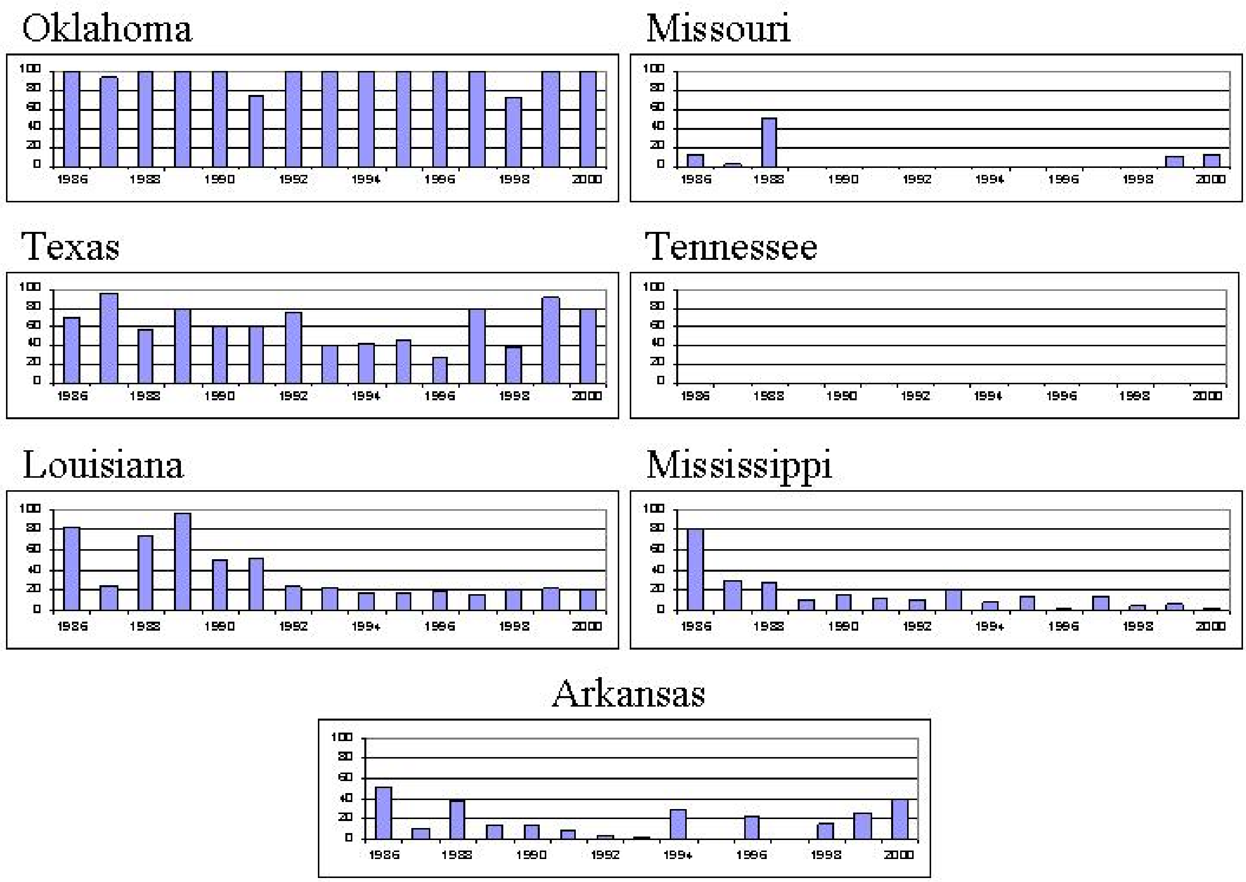

Figure 4. Percent of cotton acreage in states surrounding Arkansas with recorded infestations of cotton fleahoppers (*y axis on each graph*) for cotton growing seasons 1986-2000 (Williams 2001).

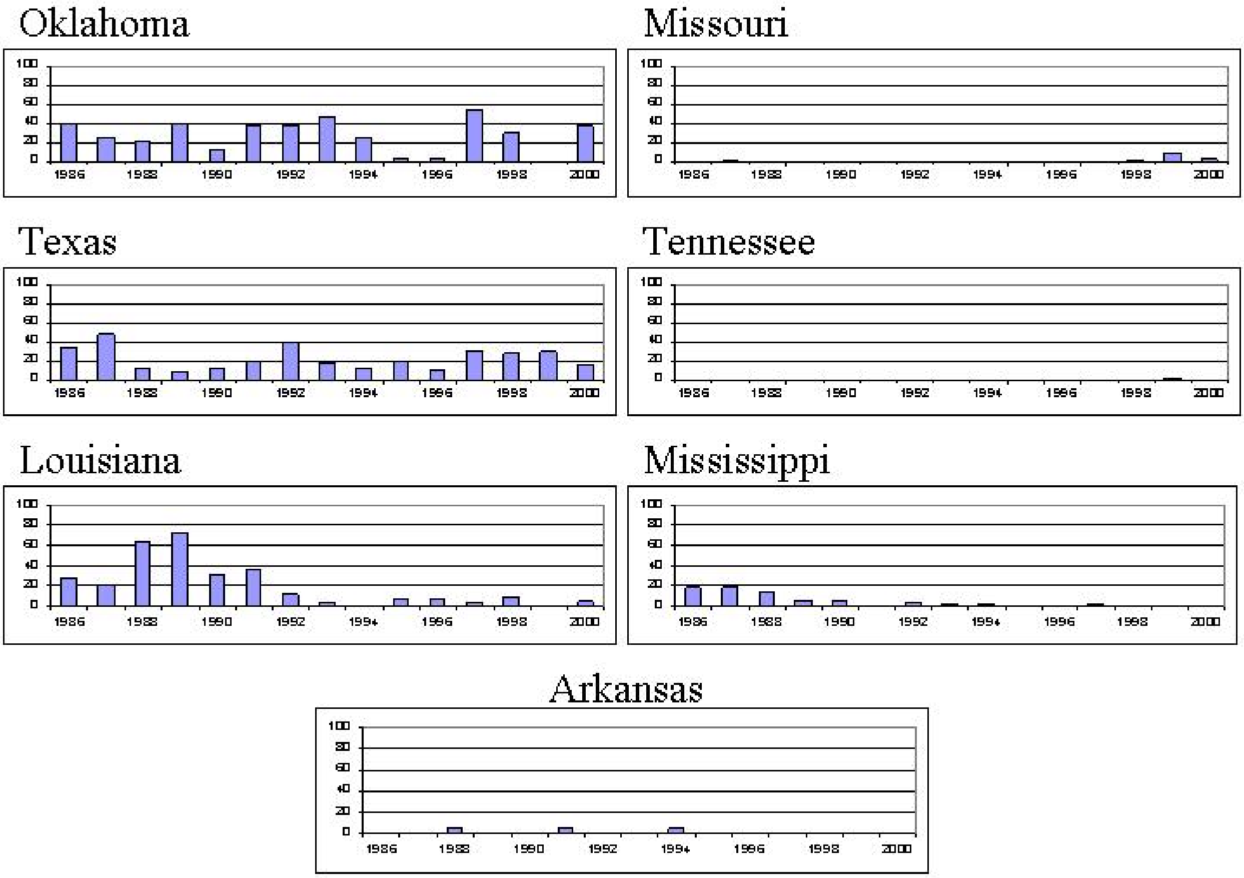

Figure 5. Percent of cotton acreage in states surrounding Arkansas with threshold densities of cotton fleahoppers (*y axis on each graph*) for cotton growing seasons 1986-2000 (Williams 2001).