ABIOTIC AND BIOTIC REGULATION OF COTTON APHID POPULATIONS IN THE TEXAS ROLLING PLAINS

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Abstract

Population development of the cotton aphid, *Aphis gossypii* Glover, was studied in dryland cotton planted in late April, late May, and late June for seven consecutive years, 1988-1994. 'Paymaster 145' cotton was grown each year at the Texas Agricultural Experiment Station at Chillicothe. Abiotic factors that were monitored included maximum daily temperature, solar radiation, and day length. Biotic factors included percentage leaf moisture and nitrogen, predator abundance, and the square/boll ratio. Multiple regression and correlation analyses were used to determine the most influential variables affecting population development. The timing of peak population densities and peak densities of aphids were governed primarily by abiotic factors. Average aphid densities were regulated by an interaction of abiotic and biotic factors, but rate of aphid population decline was regulated by biotic factors.

Introduction

The cotton aphid, *Aphis gossypii* Glover, has been a serious and persistent problem in north and west Texas since the late 1970's. In west Texas, infestation levels remain low during June and July and seldom require treatment, but populations typically begin to increase rapidly in early August, and insecticidal control may be required by mid- to late August.

Abiotic factors that affect cotton aphid populations include temperature, light intensity, solar radiation and photoperiod. Of these, the effects of temperature have been most clearly defined; Akey and Butler (1989) reported that optimal temperatures for fecundity and development were 25° and 27.5°C, respectively. Auclair (1967) reported that cotton aphid feeding and survival were best under conditions of low light intensity (54-538 lux). Rosenheim et al. (1994) reported that fecundity was two-fold higher for cotton aphids held under a 13-hr photophase as compared to those held under a 14-hr photophase. Slosser et al. (1992a) found a significant, negative correlation between solar radiation and numbers of cotton aphids in August; a measurement of solar radiation includes visible light and heat components.

Biotic factors that affect cotton aphid populations include the nutritional status of the cotton plant and biological control organisms such as predators. Slosser et al. (1992b) reported that aphid numbers were correlated with percentage leaf moisture and with the interaction between percentage leaf moisture and leaf nitrogen. Water availability in plant tissues can affect carbohydrate metabolism and amino acid concentrations (Brodbeck and Strong 1987), which may explain the significance of the interaction between leaf moisture and leaf nitrogen. Lady beetles, lacewing larvae, and syrphid fly larvae are among the predators known to be effective predators of cotton aphids in west Texas.

In this paper, we address the roles of abiotic and biotic factors, and their interactions, that govern population density after late July. This is the time period that cotton aphid populations typically increase and decrease rapidly in dryland cotton in the Texas Rolling Plains.

Materials and Methods

Studies were conducted at the Texas Agricultural Experiment Station at Chillicothe. We used three planting dates to manipulate plant nutritional status during August, and we followed population development in these three planting dates for seven consecutive years to determine how bioclimate and plant nutrition interacted to regulate cotton aphid populations. 'Paymaster 145' cotton was planted in late April, late May, and late June from 1988 to 1994. Nitrogen, at 34 kg/ha, was applied just prior to planting, and cotton was grown dryland each year. Azinphosmethyl was applied for boll weevil control during June in the late April planting in 1992, but no other insecticide applications were made during this study.

Aphids were sampled, once a week, in each of the three planting dates from the last week in July and continuing until populations declined in late August to mid-September. Leaves were picked from the top-half and from the bottom-half of the plant and immediately examined for aphids. Five leaves were picked from each plant half in 1988 and 1989, but sample size was increased to 20 from each plant half beginning in 1990. As aphid numbers increased above several hundred per leaf in mid-August, sample size was reduced to ten leaves and finally five leaves per half. Aphids were individually counted to about 100/leaf, after which numbers were estimated by counting groups containing 5 or 10 aphids. Numbers and identity of predators were recorded on each leaf examined for aphids beginning in 1990. Only lady beetle adults and larvae, lacewing larvae, and syrphid fly larvae were counted.

Leaves from the top-half and from the bottom-half of the plant were picked, once a week, to determine percentage nitrogen and moisture content. In 1989, 10 leaves were picked from each half, but beginning in 1990, 30 leaves were sampled from each plant half. Leaves were weighed, oven dried at 50°C for 72 hr, and reweighed; moisture content was calculated by difference. Leaf samples were then ground in a bench top Wiley mill and analyzed for

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Kjeldahl nitrogen. Beginning in 1992, percentage leaf nitrogen content was determined with a near infrared spectrophotometry technique (WEP, unpublished data). Leaf samples were collected within 24 hr of each sample for aphids. Numbers of 1/3-grown squares and soft bolls were determined per m of row in two locations in each plot during the growing season.

Physical environmental variables that were monitored included ambient air temperature and solar radiation. Photoperiod was calculated with the program SunTimes Plus (Zephyr Services, Pittsburgh, PA). Temperature was measured with an hygrothermograph at the Experiment Station at Chillicothe, TX, and a pyranometer located at Munday, TX was used to monitor solar radiation.

The relationships between aphid population density (dependent variable) and abiotic and biotic factors (independent variables) were determined with multiple regression analyses, using the MULTIREG routine of MSTAT-C (MSTAT Development Team 1988). The multiple regression relationships were developed by selecting from linear, quadratic, and cubic functions for each independent variable and from linear and quadratic functions for the multiplicative, two-way interactions of the independent variables. Aspects of cotton aphid populations that were investigated included timing of peak populations after early August, average and peak numbers of aphids per leaf during August, and rate of population decline in late August to mid-September. Although multiple regression equations have been developed for each planting date (Slosser et al. 1998), only the relationships for all three planting dates combined are discussed here.

Results and Discussion

The three planting dates provided cotton plants with very different stages of phenological maturity during August, when aphid populations increased. Cotton planted in late April was mature with few blooms and mostly hard bolls on the plants. Cotton planted in late May was a peak bloom production in early August, and the square to boll ratio was about 1.0. Cotton planted in late June was just beginning to bloom in early August, and there no, or very few, young bolls on the plants.

Regardless of the stage of phenological maturity effected by each planting date, cotton aphid populations increased at the same time in all three planting dates during August. Populations declined rapidly within two weeks after peak densities were attained. In three of the seven years, peak numbers occurred on the same date in all three plantings. In the other four years, peak numbers occurred on the same date in the late April or late May planting as in the late June planting. Peak populations were attained within a one week time interval in all planting dates. Numbers of aphids per leaf were highest in late-June planted cotton in six of the seven years, the exception being in 1993 when numbers were highest in late April planted cotton.

The consistency of timing of peak numbers across planting dates indicate that abiotic environmental factors were more important than plant (biotic) effects. The number of nights with minimum temperatures $\leq 20°C$, average maximum temperatures, and the interaction of these two variables adequately described the day of year that aphid populations reached peak abundance (Table 1). Maximum temperatures were averaged over 1-14 August, while number of nights with minimum temperatures $\leq 20°C$ were summed from 28 July to 14 August. High temperatures have a direct effect on aphid reproduction, while the number of nights with minimum temperatures $\leq 20°C$ probably acts indirectly to affect aphid nutrition (starch and sucrose status in the leaves).

Abiotic and biotic factors, and their interactions, regulate average aphid densities during August (Table 2). Average numbers of aphids per leaf were related to high temperatures, the interaction between percentage leaf moisture and nitrogen (%M%N), and the interaction between solar radiation and (%M%N). The square to boll ratio acted as a scaling factor to adjust for the differing phenological state of plants within and among planting dates. The independent variables were averaged from the last week in July through mid-August, while aphid numbers were averaged from the last week in July through the week of peak population density. High temperature, light intensity (as indicated by solar radiation), and plant nutrition (leaf moisture and nitrogen status) interact to regulate average aphid densities.

Peak aphid densities were regulated primarily by abiotic factors including solar radiation (which includes heat and light effects) and hours of daylight, while percentage leaf nitrogen adjusted for differences in plant phenology among planting dates (Table 3). Solar radiation values were averaged from 25 July to the day before peak aphid density, and hours of daylight were that on the day of peak density. Peak aphid density was the highest average number of aphids per leaf after early August. While interactions between the abiotic and biotic (plant) environments during August set the limits for average numbers of aphids per leaf, the physical environment was responsible for setting the limits for maximum numbers per leaf.

The rate of aphid population decline, after peak density was attained (Table 4), was regulated by biotic factors including predator numbers per leaf, peak numbers of aphids per leaf, and by plant nutrition (percentage leaf nitrogen and moisture). Within an individual planting date, predator numbers were the most important factor regulating aphid population decline, but aphid density and plant nutrition were additional factors that acted across planting dates (phenological stage). Aphid population decline was calculated as the decrease in numbers per day from the date of peak density to the next sample date (about 1 week). Predator numbers were the average numbers per leaf on the date before and at peak aphid density (two sample dates); peak aphid density was the highest numerical value in each planting date each year, and values for %M%N were the readings taken nearest the date of peak aphid density in each planting date. Parasitism and infection by *Neozygites fresenii* were not significant regulating factors of aphid populations in this study.

Summary

There was an interaction between the abiotic and biotic environments that regulated cotton aphid population increase and decrease during August and September. However, the most important factors depended upon which aspect of the population was being considered. Timing of peak population density was regulated by high and low temperatures which affected the aphid and probably plant nutrition, and leaf nitrogen slightly modified timing. Timing of peak population density was regulated primarily by abiotic factors. Average aphid population densities during August were regulated by high temperatures, solar radiation, and percentage leaf moisture and nitrogen. Thus, average aphid numbers were regulated by abiotic and biotic factors. Peak densities were regulated by solar radiation and day length, which are abiotic factors. Aphid population decline was regulated by predator numbers, percentage leaf moisture and nitrogen, and aphid density. Thus, aphid population decline was regulated by biotic factors. A detailed description and analyses of the factors that regulate cotton aphid populations were given by Slosser et al. (1998).

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Table 1. Relationship between day of year of peak aphid populations and indicated independent variables (X). 1988-94.

Independent Variable	Description	t-Value	Probability	SPRC[a]
X_1	No. Nights Temp.<= 68°F	-8.177	< 0.001	-23.187
X_2	Avg. High Temp.°F	-9.054	< 0.001	- 2.633
X_3	Interaction $X_1 \times X_2$	8.016	< 0.001	21.318

[a]SPRC = standard partial regression coefficient, R^2 = 0.829, n = 21.

Table 2. Relationship between average number of aphids per leaf (Y) and indiciated independent variables (X). 1989-94.

Independent Variable	Description	t-Value	Probability	SPRC[a]
X_1	Daily High Temperature	8.987	< 0.001	0.916
X_2	$(\%M\%N)^2$	13.036	< 0.001	1.658
X_3	Solar radiation x (%M%N)	-10.644	< 0.001	-1.663
X_4	Sqr/Boll Ratio	3.007	0.008	0.271

[a]SPRC = standard partial regression coefficient, R^2 =0.933, n=18.

Table 3. Relationship between maximum numbers of aphids per leaf (Y) and indiciated independent variables (X). 1989-94.

Independent Variable	Description	t-Value	Probability	SPRC [a]
X_1	Solar Radiation	-6.238	< 0.001	-15.249
X_2	(Solar Radiation)^2	6.014	< 0.001	14.801
X_3	Hours of Daylight	-4.422	< 0.001	-0.523
X_4	% Leaf Nitrogen	1.948	0.068	0.213

[a]SPRC = standard partial regression coefficient, R^2 =0.875, n=18.

Table 4. Relationship between rate of aphid population decline after peak population density and indicated independent variables (X). 1990-94.

Independent Variable	Description	t-Value	Probability	SPRC [a]
X_1	Predators No./Leaf	-6.304	< 0.001	-4.124
X_2	Predators (No./Leaf)^2	5.095	< 0.001	8.997
X_3	Predators (No./Leaf)^3	-4.443	0.001	-5.415
X_4	(Peak Aphid Density)^2	-6.759	< 0.001	-0.864
X_5	%M%N	-4.076	0.001	-3.136
X_6	(%M%N)^2	4.309	0.001	3.497

[a]SPRC = standard partial regression coefficient, R^2 = 0.968, n = 15.