

Economic Injury Level for the Banks Grass Mite (Acari: Tetranychidae) on Corn

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ABSTRACT Banks grass mite, *Oligonychus pratensis* (Banks), feeding on corn, *Zea mays* L., between the late-vegetative and dent growth stages caused significant yield loss but did not affect test weights. Regression analysis was used to compare several independent variables (mite abundance, damage ratings, and percentage of the leaves infested) with yield loss and plant lodging. Data were analyzed the week of maximum yield loss from mite feeding at predetermined damage levels and the week before this event. The best relationship was between yield reduction and percentage of the leaves infested the week before maximum yield loss from mite feeding occurred. There was a 0.2% yield loss per 1% infested leaves per plant. A flexible economic threshold for Banks grass mite on corn can now be calculated based on crop value and cost of control. Mite feeding on corn in the dent growth stage did not affect yield. Banks grass mite feeding did not have a definitive effect on incidence of plant lodging, although there were indications that increased lodging may have been associated with mite feeding in some situations. Grain moisture declined as densities and feeding damage by Banks grass mite increased.

KEY WORDS Arachnida, *Oligonychus pratensis*, economic injury level, corn

BANKS GRASS MITE, *Oligonychus pratensis* (Banks), has been a major pest of corn, *Zea mays* L., grown on the semi-arid high plains of the United States for about 20 yr (Owens et al. 1976). Nominal economic thresholds (Poston et al. 1983) for Banks grass mite have been developed and included in extension pest management guides in the affected states. These thresholds range from control recommendations when mites, webbing, and a few yellow areas are observed on leaves in the lower one-third of the corn plant (Schweissing 1973) to when mites, webbing, and visible damage are easily found in the middle one-third of corn plants (McWhorter 1976). Bacon et al. (1962) studied the damage potential of the twospotted spider mite, *Tetranychus urticae* Koch, on corn in California using sprayed and unsprayed treatments. They reported a 47% yield reduction in the unsprayed treatment from twospotted spider mite feeding. Mite feeding did not affect grain moisture, dry matter, nitrogen, protein, mineral matter, fiber, or fat. The incidence of stalk rot and subsequent plant lodging was higher in the unsprayed treatment.

The research presented in this paper was designed to quantify the effects of Banks grass mite feeding on corn yield and incidence of plant lodging. The relationship of Banks grass mite densities and damage to corn yield or lodging was studied for feed and food corn in the tasseling and grain-filling growth stages because increase of Banks grass mite is greatest during these stages (Ehler 1974, Feese & Wilde 1977). Many of the new miticides being evaluated for Banks grass mite control on corn require up to 1 wk following application to

provide maximum control. Therefore, research was designed to determine if an economic threshold could be delineated that would allow control decisions to be made well before feeding damage by Banks grass mite reached the economic injury level.

Materials and Methods

This research was organized in a randomized complete block design with four replications in 1984 and 10 replications in 1986 and 1987. Plots were 8 m wide (8 rows) by 15 m long. Data were collected in two, 4-m-long sections of the two center rows per plot. A yellow feed corn ('Pioneer 3186') was planted all three years, and a white food corn ('Ring Around 360') also was planted in 1984. Corn was planted the third week of April each year, and agronomic practices commonly used for producing irrigated corn were used (Petr & Bremer 1976).

Mite damage to corn was measured in each plot from the tassel through grain-filling growth stages. Mites in each treatment were sprayed (1) as needed to keep them mite free, (2) when mite feeding >10% of the total leaf area (damage rating, 1) per plant using the 1-10 damage rating scale described by Chandler et al. (1979), (3) when damage >30% (damage rating, 3), (4) when damage >50% (damage rating, 5), and (5) when damage >70% (damage rating, 7). Mite infestations were created by infesting plants with field-collected mites. Heavily infested corn leaves were collected from a commercial field and transported to the research plots. Plants were infested between 1 and 15 July (im-

mediately before pollen shed) each year depending on when an adequate infestation provided enough mites. A predetermined number of leaves was placed on plants in the sample area in each plot based on the ultimate damage level desired. These infestation levels included (1) 0% damage, no infested leaves per plot; (2) 10% damage, one infested leaf wrapped around the stalk in the lower third of the canopy on every fourth plant; (3) 30% damage, one infested leaf per every other plant; (4) 50% damage, one infested leaf per plant; and (5) 70% damage, two infested leaves per plant. When mite damage to corn reached the predetermined level per plot, monocrotophos at 0.56 kg (AI)/ha was applied in 94 liters/ha of water. Mites did not produce the predetermined damage in each plot on a single date in a year, but no more than 3 wk were required before all treatments were sprayed. Miticide was applied with a hand-carried boom using a carbon dioxide propellant at 1.5 mg/cm². Six nozzles were arranged on the boom that was held above the tassels of two rows of corn plants while spraying. The four middle rows of corn were sprayed per plot.

One week after infestation, the total number of female mites, predators, infested leaves, dead leaves, and total green leaves per plant were counted weekly on each of five plants per plot in the 4-m-long sample sections. Also, the average plant damage rating was determined per plot for whole plants and leaves in the upper, middle, and lower thirds of the canopy using the 1-10 rating scale for mite damage (Chandler et al. 1979). Corn growth stage was recorded each week for each hybrid. Yield samples consisted of collecting all ears from the plants in each of the 4-m linear sections per plot. Shelled grain was weighed, and weights were standardized for 15% moisture. Test weights were determined by measuring weight per bushel of four grain samples per plot. The number of plants lodged as a result of stalk rot was recorded when yield samples were taken in 1984 and 1987. Also in 1987, three ears were collected from each plot in a section separate from the plants used for yield samples on 24 and 29 September and 2, 6, and 9 October. Corn was shelled from each of these ears, and grain moisture measured for each of the three samples per plot using a Dole 400 grain moisture tester (Eaton, Controls Division, Carol Stream, Ill.).

Many of the miticides used to control Banks grass mite on corn require at least 1 wk following application to kill mites. Consequently, control decisions using these miticides should be made early to avoid excess damage before mite densities are reduced. Poston et al. (1983) state that economic threshold decisions must be made early enough so that control can be obtained before damage reaches the economic injury level. Therefore, it was important to find a dependable relationship that would provide a long lead time between making a control decision and reaching the economic injury level. Data were collected weekly so that results were

available for statistical analysis the week of maximum mite densities, damage, and yield loss from mite feeding in each treatment and the week before this date.

Analysis of variance (SAS Institute 1985) was used to determine differences in mite numbers, damage, percentage of infested leaves, grain yield, test weight, lodging, and grain moisture among the five treatments. Means were separated with Duncan's (1955) multiple range test ($P = 0.05$). A *t* test (SAS Institute 1985) was performed on percentage of grain loss for like damage rating treatments for feed and food corn. Linear regression analysis (SAS Institute 1985) was used to describe the relationship of mite densities, damage ratings, percentage of infested leaves per plant, and combinations of these variables on yield and plant lodging. Regression analysis was used also to describe the relationship between grain moisture and mite densities or feeding damage. Polynomial models did not provide a significant ($P = 0.05$) improvement to explain variation.

Results and Discussion

Data collected in 1984 and 1987 were used to determine the economic injury level for Banks grass mite on corn. Mite increase was slow in 1986, and most damage occurred during the dent growth stage.

The year by treatment interaction was not significant, so data for 1984 and 1987 were combined for statistical analysis. Statistical differences in Banks grass mite densities, damage, and proportion of the leaves infested were obtained among treatments for the week of maximum mite densities, damage, and yield loss from mite feeding and for the week before this event (Table 1). Maximum mite densities, damage, and yield loss from mite feeding occurred 3, 3, 4, and 5 wk after infestation in treatments 2 to 5, respectively. Proportion of the leaves infested and damage rating data for leaves in the lower, middle, and upper thirds of plants demonstrate that Banks grass mites moved up the plant early in an infestation although they did not reach leaves in the upper third of the plant until about 30% of the plant was damaged. Mite densities increased steadily until the damage rating exceeded 5, and then abundance reached a plateau. This cessation of increase in mite abundance when damage was high may have resulted from mite crowding on the plant and a decrease in leaf quality. There were significant differences among yields. Yields were a mirror image of mite densities and to a lesser extent percentage of the leaves infested or damage ratings except for leaves in the upper third of a plant. There were no significant differences in test weights among treatments.

Regression analysis was used to evaluate the effect of the following variables on yield (1) female mite densities per plant, (2) percentage of a plant or plant section damaged from feeding by mites,

Table 1. Densities and damage of Banks grass mite on corn and yield loss the week that mite densities and damage peaked in each treatment and maximum yield loss from mite feeding occurred and the week before this event

Treatment no.	Damage rating/plant section ^a				̄ No. ♀ mites/plant	% Leaves infested	Yield, kg/ha
	Lower one-third	Middle one-third	Upper one-third	Whole			
Week of maximum yield loss from mite feeding							
1	0.8e	0.0e	0.0c	0.9e	15c	25d	11,366a
2	2.4d	1.1d	0.0c	2.0d	153bc	67c	10,839ab
3	4.1c	2.0c	0.3c	3.0c	257b	77b	10,580ab
4	6.3b	4.1b	1.2b	5.2b	819a	92a	10,193bc
5	8.6a	5.8a	2.3a	6.9a	735a	99a	9,797c
Week before maximum yield loss							
1	0.8d	0.0d	0.0c	0.9d	15d	25e	11,366a
2	1.1d	0.9c	0.0c	1.0d	130cd	49d	10,839ab
3	1.8c	1.0c	0.0c	1.3c	157c	77c	10,580ab
4	5.1b	2.7b	0.4b	3.8b	440b	82b	10,193bc
5	7.0a	4.1a	1.2a	5.2a	728a	93a	9,797c

Means in each column followed by the same letter are not significantly different ($P = 0.05$; Duncan's multiple range test [SAS Institute 1985]).

^a Damage rating on a 1-10 scale when 1 = 1-10% of the leaf area damaged by mite feeding to 10 = 91-100% damage.

(3) number of infested or uninfested leaves, and (4) proportion of the leaves on a plant that were infested by mites. Results of the regression analysis demonstrated a good relationship between mite density, damage ratings, or percentage of the leaves infested and yield both weeks (Table 2). The independent variable with the highest R^2 and lowest root mean square error was not the same for the week of maximum yield loss from mite feeding or the week before this event. An adequate control decision can be made using data from either week. Combining independent variables did not increase R^2 values. Use of damage ratings for the three plant sections did not improve the relationship between yield and damage rating over that obtained with whole-plant damage ratings.

Based on a low root mean square error and a high adjusted R^2 , as used by Breen & Teetes (1986),

damage rating was the best variable to sample on the week of maximum yield loss, followed by percentage of the leaves per plant infested (Table 2). There was a 0.22% yield loss for each 1% of the leaf area damaged by Banks grass mite feeding. The relationship between yield and Banks grass mite abundance was better on the week before maximum mite densities, damage, and yield loss from mite feeding. This was the result of a positive relationship between mite abundance and damage in all treatments. On the week of maximum yield loss, densities were negatively affected when damage exceeded 50%.

The best variable to sample on the week before maximum yield loss was the percentage of the leaves that were infested on a plant. This variable is more reproducible and sampling is quicker than damage rating, which is a qualitative measure. There was

Table 2. Relationship between corn yield and Banks grass mite density, mite damage rating, and proportion of the leaves on a plant that were infested the week of maximum yield loss from mite feeding and the week before this event

Independent variable	Slope	SE	Root MSE ^a	Adjusted R^2
Week of maximum yield loss from mite feeding				
Mite (♀) density	-1.2	0.3	298.3	0.69
Damage rating ^b	-221.9	24.5	169.3	0.90
Percentage of leaves infested	-18.2	2.6	212.0	0.84
Week before maximum yield loss				
Mite (♀) density	-1.8	0.3	216.3	0.84
Damage rating ^b	-256.0	48.2	267.0	0.75
Percentage of leaves infested	-20.2	1.6	126.5	0.94

^a Root MSE, root mean square error.

^b Damage rating on a 1-10 scale, when 1 = 1-10% of the leaf area damaged by mite feeding to 10 = 91-100% damage.

Table 3. Densities and damage of Banks grass mite on feed and food corn and yield loss, 1984

Corn type	Damage rating ^a	$\bar{x}$ No. ♀ mites/plant	% Leaves infested	Yield, kg/ha	% Loss ^b
Feed	0.9e	10d	35d	11,262	—
	2.0d	249cd	78b	10,798	4
	3.0c	297cd	80b	10,394	8
	5.2b	1,096a	93a	10,057	11
	6.9a	650b	100a	9,587	15
Food	1.0e	11d	43c	9,359	—
	2.0d	142cd	75b	9,379	0
	3.0c	208cd	79b	8,611	8
	5.5b	422bc	91a	8,299	11

Means in each of the first three data columns followed by the same letter are not significantly different ($P = 0.05$; Duncan's multiple range test [SAS Institute, 1985]).

^a Damage rating on a 1-10 scale, when 1 = 1-10% of the leaf area damaged by mite feeding to 10 = 91-100% damage.

^b Percentage of grain loss was not significantly different between feed and food corn receiving similar damage ratings ($P = 0.05$; t test [SAS Institute 1985]).

Table 4. Densities, damage, and proportion of leaves infested by Banks grass mite on corn in dent or postdent growth stages and resulting yield responses

Treatment no.	Damage rating ^a			Plant	$\bar{x}$ No. ♀ mites/plant	% Leaves infested	Yield, kg/ha
	Lower one-third	Middle one-third	Upper one-third				
1	1.3e	0.3d	0.0c	1.2e	12d	25e	10,347a
2	2.8d	1.1c	0.0c	2.0d	67d	45d	10,472a
3	4.6c	1.7c	0.3c	3.4c	201c	60c	10,357a
4	6.8b	3.5b	1.1b	5.1b	358b	72b	10,593a
5	9.1a	6.2a	3.4a	7.3a	526a	94a	10,111a

Means followed by the same letter were not significantly different according to ($P = 0.05$; Duncan's multiple range test [SAS Institute, 1985]).

^a Damage rating on a 1-10 scale, when 1 = 1-10% of the leaf area damaged by mite feeding to 10 = 91-100% damage.

a 0.2% yield loss for each 1% of the leaves damaged by Banks grass mites 1 wk before maximum yield loss. Using the percentage of leaf area damaged for the week of maximum yield loss or percentage of the leaves infested the week before maximum yield loss, the economic threshold for Banks grass mite on corn can be calculated based on the cost of mite control and value of the crop.

Production of food grade corn has been increasing in the irrigated corn production region of the high plains over the past few years. Therefore, it was necessary to determine whether the same relationship between mite damage and yield identified for feed corn applied to food corn. Yields were lower for the food corn hybrid so an analysis of variance could not be used to compare yield response to mite feeding between the two hybrids (Table 3). Instead, the percentage of grain loss for treatments receiving similar damage ratings was compared (t test; $P = 0.05$) and no significant differences were found between food and feed corn.

Hanway (1971) states that little increase in grain weight occurs after kernels fully dent. The questions were asked if mite damage to corn plants after dent results in yield loss and whether the economic injury level for Banks grass mite applies only to corn before dent. Banks grass mite increase

was slow in 1986, and most damage occurred after corn was in the dent growth stage so this relationship could be evaluated (Table 4). Although plant damage and mite densities were significantly different among treatments, there was no yield loss. These data demonstrate that mite feeding during the dent growth stage does not cause yield loss.

Bacon et al. (1962) reported that feeding by twospotted spider mite on corn resulted in lower grain moisture and increased lodging from stalk rot. In 1987, there was a trend towards drier kernels as feeding damage by Banks grass mite increased from late September into October (Table 5). Regression analysis of grain moisture with mite density was significant ($P < 0.05$) at each sample date (adjusted $R^2 = 0.54, 0.42, 0.33, 0.35$, and 0.28 from 24 September to 9 October, respectively). However, the relationship between moisture and feeding damage was significant ($P < 0.05$) only on 24 September and 6 and 9 October (adjusted $R^2 = 0.44, 0.41$, and 0.56 on each of the three dates, respectively). The difference in grain moisture between ears collected from plots in the low and high damage rating treatments on 9 October (19 and 14%, respectively) in this research with Banks grass mite was similar to data reported by Bacon et al. (1962) of 19 and 15% in treatments that were

Table 5. Grain moisture in corn on plants damaged by Banks grass mites

Damage rating ^a	$\bar{x}$ No. ♀ mites/ plant	$\bar{x}$ % Grain moisture/date				
		September		October		
		24	29	2	6	9
3	2	27.1	22.8	20.6	20.0	18.9
4	42	26.1	22.4	20.6	18.7	17.1
5	15	27.8	24.1	22.4	20.4	19.3
6	251	24.9	21.6	19.0	18.6	16.4
7	187	24.1	21.3	19.6	17.3	15.1
8	380	22.5	19.3	18.3	16.6	14.1

There were no significant differences in grain moisture among plants receiving any level of mite feeding damage for each date ($P = 0.05$; [SAS Institute 1985]).

^a Damage rating on a 1-10 scale, when 1 = 1-10% of the leaf area damaged by mite feeding to 10 = 91-100% damage.

Table 6. Corn plant lodging in plots infested with different numbers of Banks grass mites

Damage rating ^a	% Plants lodged (% increase over 0 damage treatment)		
	Yellow feed corn		White food corn
	1987	1984	1984
0	17 (—)	3 (—)	21 (—)
1	25 (1.5)	3 (1.0)	20 (1.0)
3	29 (1.7)	2 (0.7)	33 (1.6)
5	32 (1.9)	7 (2.3)	28 (1.3)
7	33 (1.9)	8 (2.6)	31 (1.5)

There were no significant differences in percentage of lodged plants in each column or in percentage of increase in lodging among years or hybrids at each damage rating ($P = 0.05$; [SAS Institute 1985]).

^a Damage rating on a 1-10 scale, when 1 = 1-10% of the leaf area damaged by mite feeding to 10 = 91-100% damage.

sprayed or not sprayed for twospotted spider mite control, respectively.

The percentage of corn plants that lodged varied among years. Therefore, to provide a standard measure for statistical analysis, the percentage of increase in lodging as damage rating increased was calculated. There was no significant difference between years or between food and feed corn hybrids (Table 6). Regression analysis was not significant for comparisons between plant lodging and mite densities, damage rating, or percentage of plant infested when data were combined for the 2 yr (adjusted R^2 ranged from 0.01 to 0.18). When regression analysis was done for each year, it was found that some adjusted R^2 values were significant (adjusted R^2 for significant relationships were 0.83 for damage in 1984 and 0.94 for mite densities and 0.79 for damage in 1987). The failure to obtain a consistent relationship for the two years indicates that management decisions concerning lodging resulting from mite feeding cannot be made with accuracy.

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