

VERTICAL WITHIN-PLANT DISPERSAL OF BANKS GRASS  
MITE OLIGONYCHUS PRATENSIS (BANKS) (ACARI:  
TETRANYCHIDAE), ON CORN ZEA MAYS L.

by

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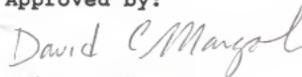
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## Introduction and Literature Review

Spider mites of the family Tetranychidae are found worldwide on ornamental and agricultural plants (Jeppson et al., 1975; Chandler, 1978). One member of this family, the Banks grass mite (BGM), Oligonychus pratensis (Banks), is a serious pest of corn, wheat, and sorghum in the Western Great Plains and other semi-arid regions of the Western United States (Pickett and Gilstrap 1985; Mock et al. 1981; Depew 1960; Owens et al. 1976). BGM has been reported in Arizona, California, Colorado, Florida, Georgia, Hawaii, Idaho, Kansas, Louisiana, Missouri, Montana, Nebraska, Nevada, Texas, and Washington (McGregor and Stickney, 1965; U.S.D.A., 1972; Jeppson, et al., 1975; Chandler, 1978; Mock et al. 1981).

The Banks grass mite (BGM) was first described as Tetranychus pratensis by Banks in 1912 from specimens collected on Timothy grass in Pullman, Washington (Walter, 1955). Pritchard and Baker (1955) combined types from dates (McGregor, 1939) and grasses and all were named as Oligonychus pratensis (Banks) (Elmer, 1965; Walter, 1956;).

BGM utilises grasses as a host (Tuttle and Baker, 1968). Economically important hosts include wheat, corn, sorghum, sugar cane, dates, bluegrass, and bermuda grass (Chandler, 1978). BGM adults have been found on Johnson

grass and other perennial grasses during the winter months (Ehler 1974, Buschman and Dick 1981). Holtzer et al. (1984) collected immature BGM in Nebraska, during Feb. and April, indicating that these immatures resulted from reproduction that occurred during the winter. Adults collected by Holtzer et al. in Jan. were all diapause-form adults, but recovered their "summer" coloration and began ovipositing within 3 days when placed on corn at 25 C.

Studies on the life history of BGM have been performed by Tan and Ward (1977), Congdon and Logan (1983), and Perring et al. (1984ab). Tan and Ward (1977) found that BGM, when reared in the laboratory on sorghum under an average temperature of 32.5 C, had a life cycle of 7-13 days and the the total length of life varied from 14-36 days. Six to 14 eggs were laid per female per day with a maximal oviposition on the 6th day of adulthood, and an average of 151 eggs laid per female over the lifetime. Congdon and Logan, (1983) developed similar data for BGM on Blue grama grass. Maximums were only slightly lower, leading Congdon and Logan to suggest that the life history parameters of BGM feeding on cultivated crop hosts vs wild grass hosts were not significantly different.

Perring et al. (1984a) performed a comprehensive study on the influences of temperature and humidity on

pre-adult BGM development, and on ovipositional rates, fecundity, and longevity of adult BGM. They found that BGM development was influenced primarily by temperature. Up to a certain maximal point, higher temperatures resulted in faster development. Humidity effects within any given temperature were small with the exception of a low vapor pressure deficit, or very high humidities which were detrimental to development. Total immature developmental time ranged from a minimum of 4.9 days at 36 C to a maximum of 12.6 days at 23 C. They also pointed out that the time required for egg hatch constituted nearly 50% of the overall immature developmental time. This is also obvious in previous data eq. Tan and Ward (1977). Adult longevity was found to be influenced more by temperature than humidity, although at high temperatures there was a slight tendency for longevity to be greater at high vapor pressure deficits. Ovipositional period and total number of eggs per female were strongly influenced by temperature. When temperatures are optimal for BGM development (near 37 C) low humidity increases survival and ovipositional rates (Perring et al. 1984b).

Toole et al. (1984) suggested that microenvironmental factors that influence canopy and soil surface temperatures have important, direct effects on BGM population dynamics. For example, stomatal

closure due to plant-water stress and decreased windspeed causes elevated leaf temperatures. These effects could be detrimental to BGM population development if temperatures are too high, but could be beneficial if the temperatures are optimal for development (Toole et al 1984).

Microenvironmental factors are just one aspect of a species habitat. Another aspect that affects an organism is the duration that its habitat is available for occupation. Habitats may, in general, be classified according to their stability (Southwood 1962). The habitat of BGM, in the system with which I work, is ephemeral or short-lived, lasting only a single growing season. To increase the chance of survival throughout the season, spider mites have evolved the ability to locate new resources so that survival and reproduction would endure. According to Mitchell (1970, 1973) tetranychid mites have evolved several methods of increasing their ability to disperse, and thus increasing their chances of survival. He suggests, that for the twospotted spider mite (TSM), Tetranychus urticae survival and reproduction are enhanced by increasing the number of female offspring produced, while at the same time delaying their growth to full size, until after they disperse. This adaptation would maintain the yield of dispersing females at a high level

while the growth and food requirements of the family declines. Requirements decline since the immatures and males remaining feed less than the dispersing female (Boudreaux 1958).

Another adaptive advantage is that males are much smaller and less abundant than females, so most of the standing biomass is female. Mating usually occurs immediately after emergence of the female; thus, virtually all active females are mated and capable of founding a colony ( Mitchell 1970, 1973). These adaptations also appear to be true for BGM.

Both Banks grass mite and twospotted spider Tetranychus urticae Koch are pests of corn in the Midwest (Logan et al. 1983; Pickett and Gilstrap 1985). While both species might infest corn at the same time, ecological and behavioral differences exist between the two species. The twospotted mite has a much wider host range and has been more widely studied especially in the areas of dispersal methods and behaviors.

Dispersal behavior of the TSM has been examined in the corn/peanut agroecosystem of North Carolina. Brandenburg and Kennedy (1982) found that crawling from overwintering hosts, such as clover, blackberry, and wild violet, was a primary means of mite entrance into corn early in the season. When corn became an unsuitable host, either because of crowding or host

deterioration, adult female TSM crawled to the tips of corn plants and were dispersed as aerial plankton to nearby host plants, in this case peanuts.

The behavior expressed by overcrowded mites or mites under a food shortage was distinctive. They exhibited a change in phototactic response from negative to positive, thus now responding to light, and moving up the plant to leaf tips (Suski and Naegele 1963; Brandenburg and Kennedy 1982). If wind was encountered, the mites oriented facing away from the light, and rose their forelegs and forebody. This behavior is believed to increase the chances of being lifted from the surface and dispersed in the wind and on updrafts (Smitley and Kennedy 1985).

In contrast to the TSM dispersal behavior, the highest densities of BGM are found on the lower leaves of a corn plant, but they slowly move to the higher parts of the plant as the lower leaves die from damage or old age (Gilstrap et al. 1980).

In Kansas and other Midwestern states, the sequence of host plants for TSM and its time of appearance differs from that in N. Carolina. In Kansas, TSM usually appears on corn later in the season than BGM. It has been reported that TSM populations build up on various other hosts plants, then disperse to corn in mid- to -late season (Logan et al. 1983). TSM

populations developed suddenly on any portion of the plant. This random spatial pattern would be expected on mature corn plants if the major source of inoculum for TSM is mid-season, wind-dispersed immigration (Logan et al. 1983). With the exception of the order of crop infestation, the dispersal methods and behaviors of TSM from Kansas, are virtually identical to that of N. Carolina ( Brandenburg and Kennedy 1982, Logan et al. 1983).

In comparison, BGM mite populations are usually found to infest corn in early spring as they disperse from adjacent senescing winter hosts such as winter wheat and Bromus spp. (Gilstrap et al. 1980, Buschman and Dick, in press). Holtzer et al. (1984) reported that BGM colonies are founded by active mites that have moved into a field rather than by mites that have survived within the field in a dormant state. This was supported by their failure to find live mites in field debris in late winter, and their observation that infestations started on border rows between senescing and new hosts (such as winter wheat to corn). Knowledge on the distribution of mites on a plant is important for devising sampling programs or methods to estimate field populations.

Estimating mite densities in a field is difficult, so over the years, several methods of sampling mites

have been devised. One method was to select 10 heavily infested leaves from plants, and counting all life stages in a 0.6 in diam. microscope field on the most densely infested area of each leaf (Ward et al. 1972). Other methods were to rate damage on infested plants (Schweissing 1968), and counting the total number of female mites per plant (Ehler 1974).

Gilstrap et al. (1980) proposed that if mites are distributed on corn plants in a predictable pattern, a portion of the leaves per stalk might be selected as acceptable sample units to estimate mite populations. They found that BGM were aggregated on the bottom portions of all plants (bottom-most leaf = leaf position 1), usually with a decisive peak at leaf positions 3, 4, 5, or 6. Also, more leaves at lower leaf positions tended to be infested than leaves on the upper half of the plants regardless of the age or condition of the plant. They suggest that BGM samples could be restricted to counts of female mites at leaf positions 1-6 when sampling to quantify population density or to detect incipient infestations.

It has been suggested that aerial dispersal may be a component in the life history of BGM (Holtzer et al. 1984; Pickett and Gilstrap 1986), but no aerial dispersal was tested. However, Margolies (1987) tested BGM in the laboratory and described a behavior similar

to the aerial dispersal behavior reported in TSM. Margolies found that BGM exhibited a response to wind and light identical to that described by Smitley and Kennedy (1985), but BGM dispersal responses were significantly lower than in TSM. Margolies suggested that the differences between BGM and TSM in their aerial dispersal responses is possibly due to the wide host range of TSM compared to that of BGM. TSM populations apparently use many alternative hosts throughout winter and spring and then secondarily colonize corn, whereas BGM appears to be closely associated with corn throughout the year (Logan et al. 1983). In an evolutionary sense, whether and when to abandon a deteriorating habitat must depend on the risks involved in staying vs leaving (Southwood, 1962). Risks incurred in leaving may be less for TSM because their broader host range makes it more likely they will encounter a suitable host when dispersing as aerial plankton (Margolies 1987).

Habitats of most mites are discontinuous and transient, and their populations usually consist of separate colonies that must regularly move from an exhausted resource to a new host (Mitchell 1970). Banks grass mite is found on different crop hosts throughout the growing season. Its ability to infest consecutive crops such as wheat and then corn, enhances its status

as an agricultural pest. As BGM host suitability varies, one aspect of its adaptive abilities is shown through its ability to disperse (Margolies 1984; Southwood 1962, 1977). Spider mites dispersal to or from a host is a response or reaction to the quality of that host, and within the host plant itself, different regions or areas may be better suited for habitation or as a food source. The age, nutrient content, or microenvironment of certain regions of a host plant might contribute to mites aggregations on that area over other areas of the plant, thus might lead to distinctive dispersal patterns to those areas or away from other areas.

The present study was concerned with mite distribution on a single plant basis. Our objectives were to quantify the movement inferred from the distribution of BGM within a single plant, in hopes that such information might provide a stepping stone to understanding BGM dispersal throughout the entire crop. My research focuses on identifying the "preferred" or most acceptable regions of a corn plant, and deciphering factors that affect why mites stay or move. Analysis of biotic aspects of the mite / corn interaction and the quantification of their effect on mite distribution within a corn plant may assist future researchers in the development of a predictive model of mite distribution.

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PART I

VERTICAL WITHIN-PLANT DISPERSAL OF ADULT FEMALE BANKS

GRASS MITE, OLIGONYCHUS PRATENSIS (BANKS),

ON CORN, ZEА MAYS L.

### Abstract

The objective of this study was to determine the vertical within-plant dispersal of the adult female Banks grass mite, Oligonychus pratensis (Banks), on field corn Zea mays under field conditions.

Adult female BGM were placed on corn plants by leaf position. Density levels of 25, 50, and 100 were employed in 1986-87 and levels of 50, 100, and 200 were used in 1988. Two growth stages of plants were infested: whorl (5-8 leaves fully expanded) and tassel. One to 3 days after initial infestation, leaves were cut off the plants one at a time and the number of mites on each leaf position was recorded. Mite movement from original infestation and percentage recovery of mites were calculated. Analysis examined the effect of initial density and site of infestation on these parameters.

Percentage of mites recovered was relatively low. Density effects were present in 1986-87 data, recovery percentages at the 25 and 50 density level were significantly lower than the 100 level ( $P < .05$ ), but were probably a factor of the low initial density used. No density effects were found in 1988 when density levels were increased.

Mite movement was consistent in 1986-87 and 1988 data. Adult female BGM placed on leaf positions 1-9 of corn plants were found to: 1) move up the plant slightly

when placed on leaf positions 1 and 2, 2) move down the plant when placed on leaf positions 5-9, and 3) tended not to move off of leaf positions 3 and 4 when placed on those positions. Growth stage of corn did not affect distribution of BGM in this study.

This pattern of movement or distribution was discussed in relation to possible differences in leaf chemistry, microclimate at different heights on the plant, and crop canopy coverage. Explanations for differences that exist between patterns of dispersal in natural vs artificial infestations of BGM are also discussed.

## Introduction

The Banks grass mite (BGM) Oligonychus pratensis (Banks) is an important pest of corn, wheat, and sorghum on the Western Great Plains and other semi-arid regions of western United States (Ward et al. 1972; Tan and Ward 1977; Ehler 1974). In these areas the BGM usually infests corn in early spring as they disperse from adjacent senescing wheat fields (Gilstrap et al. 1980). Holtzer et al. (1984) reported that BGM colonies are initiated by active mites that have moved into a field rather than by mites that have survived within the field in a dormant state, because no live mites were retrieved from field debris in late winter, and infestations usually started on border rows between senescing and new hosts.

This study was done to test the vertical distribution of BGM within a single plant. Past research found that BGM usually colonized the lower leaves of a corn plant first, slowly moving up the plant as the lower leaves die from mite damage or old age (Gilstrap 1980). It is assumed that BGM disperse from senescing wheat, crawl to adjacent corn, finding the lower leaves to colonize first. Little is known about possible wind dispersal of BGM; it is possible that they land as aerial plankton on corn plants, and disperse down the plant to settle on selected leaves (Margolies

1987). But, what is not entirely known is why BGM are so abundant on the lower leaves of a plant vs other areas of the plant.

Perring et al. (1983) suggested that the alteration of nutrient concentrations in the leaves of a maturing plant may either increase or decrease its value as a spider mite food source. But, it is not known if BGM can differentiate between sites on a plant that may be nutritionally better to them. They may be responding to other stimuli such as light, microenvironment, or predators.

This study was undertaken to determine if adult female BGM colonize where they first land on a host plant, or if they disperse to specific or more suitable areas of the plant. BGM females were placed on different parts of the plant and subsequent dispersal or distribution patterns were examined.

## Methods and Materials

Field experiments were conducted at Tuttle Creek Research Area in Pottawatomie County, Kansas over 3 growing seasons, 1986-88. Pioneer 3377 corn was planted on 3-4 dates each year, approximately 3 wks. apart so that simultaneous tests could be done on corn at different growth stages throughout the growing season. Standard agronomic practices were used, and in 1988 irrigation was used as needed. No plants were irrigated while experiments were in progress.

Banks grass mites were all from a laboratory colony started from field collected mites the previous year. The colony was maintained on corn seedlings at a photoperiod of 14:10, a relative humidity of 38-45%, and a temperature range of 80-87 F.

Only adult female BGM were used in this experiment. Mites were assumed to have mated, as mating usually occurs immediately after ecdysis to an adult (Potter et al. 1976) Mites were anesthetized with CO<sub>2</sub> and knocked off of corn leaves onto white paper ringed with clove oil (clove oil used to keep mites within confines of the paper). Adult females, of undetermined age, were removed from the paper with a fine camel hair brush and placed on cut corn leaf sections on wet cotton in petri dishes. Groups of 25, 50, 100, or 200 mites were placed on each leaf section. Once the desired number of mites were on that section, the petri dish was covered

and stored in the refrigerator until all mites needed that day had been collected. Replications conducted in 1986 and 1987 used populations of 25, 50, or 100; while replications done in 1988 had populations of 50, 100, or 200 mites. Each replication used 12-36 plants. Each plant had one of the known populations released on it, and each population group was represented a maximum of 4x per replication.

A cut leaf section with a known population of mites was pinned to the underside of a specific leaf on each corn plant, the underside being the normal location of natural BGM infestations (Tan and Ward 1977). Leaves were numbered consecutively from the bottom of the corn plant, with leaf position 1 being the lowest leaf that was at least 1/3 green. Adjacent plants were removed to inhibit inter-plant movement. Before cut leaf sections were pinned upon the plants, the leaves were wiped down with wet cotton to remove any arthropods (such as predators, no natural infestations of BGM or TSM were detected) already present. One to three days later, depending on the year, all leaves were cut off the plant, and the number of mites on each leaf were counted. Mites were seen to move off of leaf sections as soon as they were pinned on the plant, and the leaf sections dry out within a 24 hr. period after being pinned on the plant. Preliminary studies indicated that

most movement ended after 24 hrs.

Two measurements, mite movement from initially infested leaf and mite recovery percentage were calculated. Mite movement measures the movement of mites in relation to leaf positions. Mite movement was calculated by first calculating an average leaf measurement. This was leaf position on which a mite was recovered, multiplied by the number of mites found on that leaf. That value was divided by the total number of mites recovered of the initial density. Mean mite movement from a leaf position was then found by subtracting the average leaf value from the initially infested leaf position. Negative mite movement numbers denote movement down the plant a specified number of leaf positions, while positive values denote movement up the plant a specified number of leaf positions. For example, if mites initially infested upon leaf position 1 had a mean mite movement of 1.5, it means that the mites are moving up the plant an average of 1.5 leaf positions. Recovery percentage was the percent mites recovered of the initial density level infested upon the plant. A randomized block design was employed for all replications. A paired t-test was used to see if growth stage of corn had any bearing on mite distribution patterns, our results showed that it did not. Data from the various replications on different corn stages were therefore pooled for further analysis. Data was then

analysed using an Anova LSD T-test and a GLM least squares F-Test. LSD was used to make pairwise comparisons among a set of population means. The average leaf on which mites were recovered and the percentage of mites recovered were the dependent variables. GLM, with the dependent variables of percent mites recovered and movement from infested leaf, was used to test for interactions between the independent variables of density and initially infested leaf position.

## Results

In 1988, recovery percentages were pooled for all densities as analysis found no density effects on the recovery percentages. Recovery of mites tended to be higher on the lower leaf positions (Table 1, Figure 1). Results on leaf positions 8 and 9 are questionable due to small sample sizes (4 for each).

In the 1986-87 data set, GLM analysis showed that density affected mite recovery ( $P < .05$ ). When data was pooled over all leaf positions (Table 2), recovery of mites at the 25 and 50 mites/plant population level was significantly lower than recovery at the 100 mites/plant level. Results were then separated by leaf position and density level, and it was found that recovery of mites placed on leaf position 2 at the 25 mites/plant level was significantly lower than at the 100 mites/plant level (Table 3, Figure 2). Overall, recovery tended to decrease as leaf position increased, and recovery was generally lower at the lower mite densities than at high mite densities.

For mean mite movement, results were pooled within each data set as GLM analysis showed no effect of density on mite movement ( $P > .05$ ). BGM moved up the plant slightly when placed on leaf positions 1 and 2, but in 1986-87, movement was not significantly different from zero on leaf position 1 and 2 (Table 4, Figure 3).

In the 1986-1987 results, mites placed on leaf position 3 did not move much while in 1988 (Table 5, Figure 4), they tended to move up the plant slightly. Movement was not significantly different from zero in both data sets. Movement of mites placed on leaf position 4, in both cases, was not significantly different from zero. Downward movement of mites placed on leaf positions 6-9, tended to be greater for mites placed on higher leaves. The changes in average leaf positions is interpreted as mean mite movement.

## Discussion

Differential mite recovery percentages might have been influenced by the position on the plant of the initial infestation or by predation from natural enemies. Spraying of research plots to reduce natural enemy populations was not possible in the research area, and predators (minute pirate bug nymphs, lacewings, and various ladybug spp.) were observed feeding on mites used in the study. Lower recovery rates at higher leaf positions could be caused by greater exposure to unfavorable microclimates. Because those mites infested upon upper leaf positions tended to move greater distances than those infested upon lower leaf positions, percentage recovery could also be a factor of distance moved. Recovery tended to be lowest on upper leaves where mites moved the longest distances. There is probably a higher risk of a predator encounter, encountering unfavorable climatic conditions, or leaving the plant (walking off, dropping off, or being blown off the plant) involved with walking longer distances. Density effects on recovery rates in the 1986-1987 data set were probably due to the low initial densities used. When the density levels were changes from 25-50-100 to 50-100-200 in the 1988 replicates, no density effects were found.

Movement of BGM was similiar in the two data sets: Up slightly from the lower leaves, and down the plant

longer distances as infested leaf position increased above the third and fourth leaf positions. The data suggests that certain areas of a plant are less 'preferred' by BGM than other areas. Mites may aggregate in certain areas of a plant because there is no stimulus for them to move from that area, or they are stimulated to stay in that area. Mites may be responding to unfavorable or favorable areas of a plant in a kinetic manner. They become more active in an unfavorable environment and this activity or movement eventually lands them in an area of the plant that does not stimulate them and activity or movement ends. (Fraenkel and Gunn 1961). Several factors such as light, microenvironment, or predators could activate a dispersal response in mites.

Spider mites such as the two-spotted spider mite (and most likely BGM) are normally not responsive to light, but will respond positively to light when host plants are highly deteriorated and overcrowded (Suski and Naegele 1963). They respond by dispersing to leaf tips on the upper-most leaf positions, probably to increase the likelihood of being aerially dispersed to new food sources (Suski and Naegele 1963, Smitley and Kennedy 1985). Host plants in this study were not deteriorated or overcrowded, and the dispersal patterns found in this study do not resemble those found of mites

that occupy a deteriorating resource. It is unlikely then, that reaction to light was a factor of dispersal in this study.

Microclimate of the leaves could possibly account for the movement up the plant of some mites, while others move down. The corn plant, in a field situation, most likely has a gradient of microclimates along its height (Toole et al. 1984). Given the microclimatical conditions, there are probably some areas of the plant that have conditions unfavorable for BGM. Mites finding themselves in one of these areas may react by walking randomly until they occupy a more favored area. BGM probably respond when a certain threshold or stress level is exceeded, movement ends when this stress has lessened to an acceptable level. Mites are probably not walking in a particular direction, but are probably reacting to the microenvironmental gradient in a trial and error manner, eventually stopping where the stress factor ends or positive factors begin. The variations in distances moved are probably a factor of an individuals threshold level to stress and differences in the plants themselves in the microenvironmental gradients. Toole et al. (1984), in a study of simulated BGM population dynamics as a sub-system of a crop canopy-microenvironmental model suggests that in semi-arid hot regions (like Kansas), spatial and temporal variation in canopy microenvironments can play an

important role in determining where and when spider mite outbreaks will occur.

Movement from the infested leaf could be caused by predator pressure, and their presence may have caused movement up or down the plant. Why predators would incite movement from some positions and not others (leaf positions 3 and 4) is puzzling. If it was the natural tendency of the predators to search for prey only on upper and lower leaf positions, then predators may have been responsible for the distribution pattern that was found. Dispersal by crawling to other plants or plant parts has been shown to occur in response to the presence of predators (Bernstein 1984), but in this study there is no evidence to either support or refute this possibility. Defensive or escapist movement would probably cause the mites to spread out along the leaf they were on, or drop off the leaf. Escape would probably involve just enough movement until the mite was no longer stressed, for example out of the touching or sensory range of the predator.

BGM might be moving not because an area is disadvantageous, but because another area affords an added advantage. It might be that certain areas are more palatable or nutritious in some manner, and that increased feeding increases egg production, as oviposition is highly correlated with feeding rate

(Boudreaux, 1958). Some researchers have suggested that plant components such as N, P, K, and sugars or that changes in the levels of these components might influence mite feeding. As such, BGM may be moving in a non-random manner to a location that offers an increased fecundity. It has also been suggested, that certain growth stages may be more suitable as a host (Perring 1983; Feese and Wilde 1977; Mitchell 1970). Analysis of our data showed that growth stage did not affect mite distribution, but it is not known whether alteration of nutrients at different growth stages affects distribution of mites.

Natural field infestations of BGM are usually found to begin in early spring as BGM leave senescing adjacent wheat fields to enter corn (Holtzer et al. 1984). Initially, BGM colonizes the lower leaves of a corn plant, slowly moving up the plant as lower leaves die from feeding damage or old age (Gilstrap et al. 1980). Natural infestations might be starting at the bottom of the plant because mites are crawling onto the plants from wheat fields and encounter the lower leaves first. Aerial dispersal of behavior of BGM has been studied in the laboratory (Margolies 1987), but it has not been proven to occur in the field. BGM probably do not move from the lower leaves of the plant until they become stressed due to unfavorable microenvironmental conditions, caused by deteriorating leaf condition, or

because of stress due to overcrowding. The mites may disperse to an area of the plant that lowers stress to below a threshold level. The new area would probably be on a leaf position higher up the plant as moving down would place the mite in an already deteriorated area. The next highest leaf position on the plant would probably be where mites would stop, as the factors that elicited stress have probably not reached a threshold level there as of yet. Factors that may contribute to the differences found between BGM's natural infestation dispersal patterns and the pattern found in this artificial infestation study are site of initial infestation and crop-canopy coverage.

Mites in a natural infestation inhabit the bottom-most leaves of a plant and move up as leaves deteriorate. With the lower leaves then unfavorable, the only direction BGM can disperse on the plant is upwards (if just accounting for within-plant movement). In the artificial infestation study, mites had the option in almost all cases (except for leaf position 1) to disperse either up or down. The direction of movement was probably a function of unfavorable conditions in the immediate vicinity of the mite, and the direction (up or down) was that which relived the stress of occupying that area. Since the pattern of dispersal in artificial infestations was consistent, it

seems probable that the leaf positions from which mites moved were for some reason consistently unfavorable.

Another factor that might contribute to the differences that exist in the dispersal patterns of natural vs artificial BGM infestations is corn canopy coverage. In natural infestations the corn canopy is usually quite closed, with little space between plants. This might have the effect of decreasing the microenvironmental gradient amongst leaf positions by buffering environmental changes. In the artificial infestations of this study, plants surrounding infested plants were removed so no plant-to-plant dispersal could occur. This had the effect of opening the canopy and making the plants more exposed to the elements. This might have produced a more abrupt microenvironmental gradient between the leaf positions depending on factors such as soil surface temperature, angle of leaf to the sun, wind, and relative humidity. Toole et al. (1984) suggested that factors that influence the microenvironment of corn canopies also influence BGM population growth. If differences in microenvironmental gradients could influence mite dispersal, then canopy coverage (which influences microenvironment) would indirectly, also, affect mite dispersal.

The populations of adult females used in this study consisted of a cross-section of various-aged adults.

Given this, the various reproductive states of the individuals probably differed. Kennedy and Smitley (1985) suggested that for the TSM, ovipositing females show less tendency to emigrate from a leaf than do pre-ovipositional females. Also, that dispersal by pre-ovipositional females has the effects of prolonging the food available to the established colony, more fully exploiting the available colony sites on the host and 'spreading the risk' of colony extinction resulting from local biotic and abiotic factors. These tendencies probably apply to BGM as well. If differing aged females showed unequal tendencies to disperse, then this could account for some of the variability found in the distances moved by individuals.

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**Table 1. Percentage Recovery of BGM  
After Initial Infestation.  
Pooled data, 1988**

Leaf Position Initially Infested	Percent Recovery	Std. Error
1	.44 abc	.07
2	.50 a	.06
3	.47 ab	.07
4	.36 abcd	.06
5	.34 bcd	.06
6	.29 bcd	.08
7	.20 d	.08
8	.40 abcd	.13
9	.17 cd	.13

\* Means are least square means

\* Means followed by the same letter within a  
column are not significantly different  
( $P < .05$ ).

Figure 1. Percent recovery of BGM after initial infestation. Pooled data, 1988. Means are least squares means. Means followed by the same letter are significantly different.

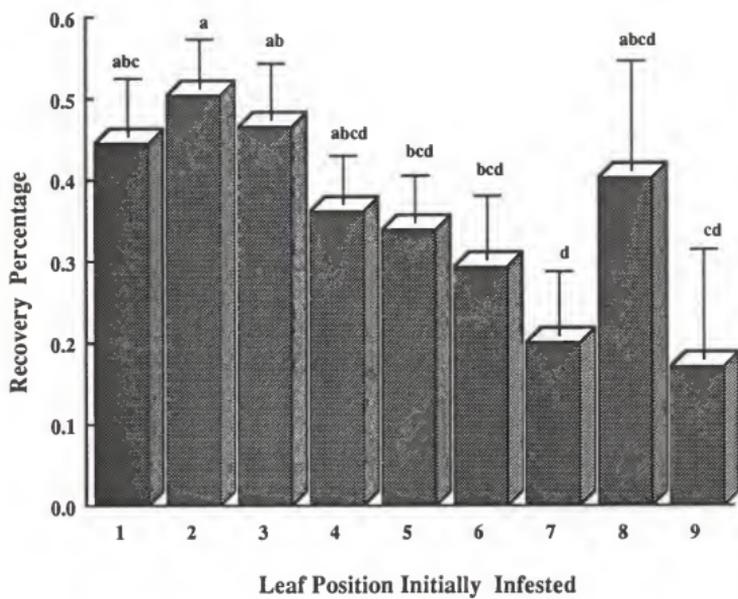


Table 2. Percentage Recovery of BGM After Initial Infestation. Pooled over all leaf positions. 1986 & 1987.

Density Level	Mean Recovery Percentage	Std. Error
25	16.31 a	4.22
50	14.66 a	4.32
100	25.25 b	2.97

\* Means are least square means.

\* Means followed by the same letter within a column are not significantly different.

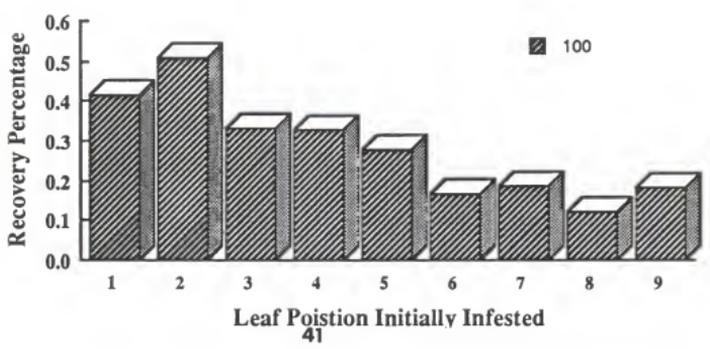
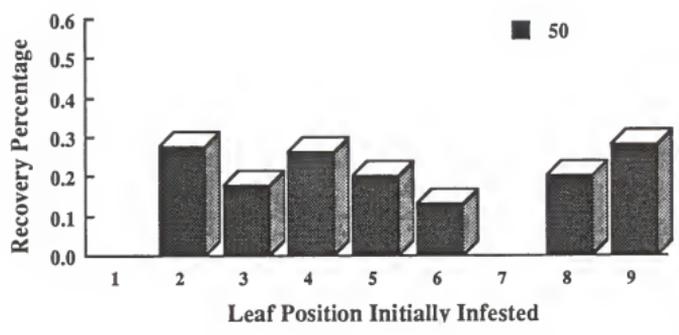
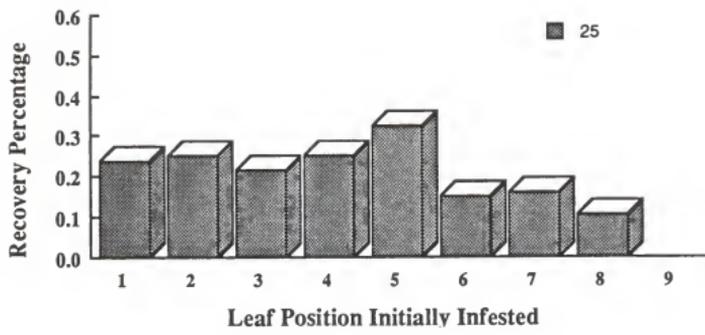
Table 3. Percentage Recovery of BGM After Initial Infestation, by density level 1986 & 1987.

Leaf Position Initially Infested	Mean Recovery Percentage		
	Density Level		
	25	50	100
1	24.00	-	41.67
2	25.14 a	27.60 ab	50.71b
3	21.33	18.00	33.00
4	25.33	26.40	32.80
5	32.67	20.00	27.83
6	15.00	13.00	16.80
7	16.00	-	18.44
8	10.67	20.00	11.75
9	-	28.00	18.00

\* Means are LSD means.

\* Means across columns followed by the same letter are not significantly different.

Figure 2. Percent recovery of BGM after initial infestation. Separated by density. 1986-87. Means are LSD means. Means followed by the same letter are not significantly different.



**Table 4. Mean Movement of BGM From  
Initially Infested Leaf.  
1986 & 1987**

Leaf Position Initially Infested	Mean Mvt.	Std. Err	P-value
1	1.13 c	.58	.0542
2	.28 c	.22	.2128
3	-.003 bc	.25	.9897
4	-.27 b	.23	.2502
5	-.62 ab	.28	.0261
6	-1.03 a	.28	.0004
7	-1.16 a	.36	.0016
8	-1.44 a	.43	.0012
9	-1.80 a	.67	.0079

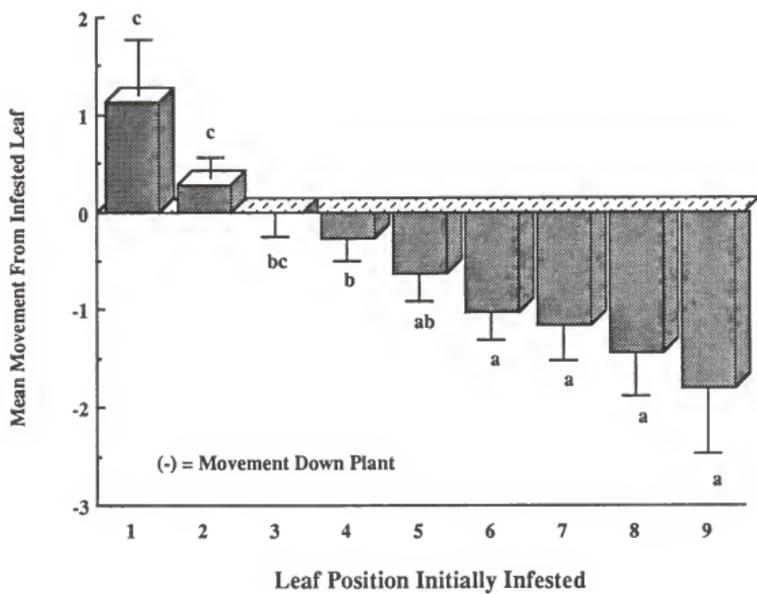
\* Means are least square means.

\* P-value, Probability values. Probability values less than 0.05 indicate movement significantly different from zero.

\* Means followed by the same letter within a column are not significantly different ( $P < .05$ ).

\* (-) signifies movement down plant from infested leaf.

Figure 3. Mean movement of BGM from initially infested leaf. Pooled data, 1986-87. Means are least squares means. Means followed by the same letter are not significantly different.

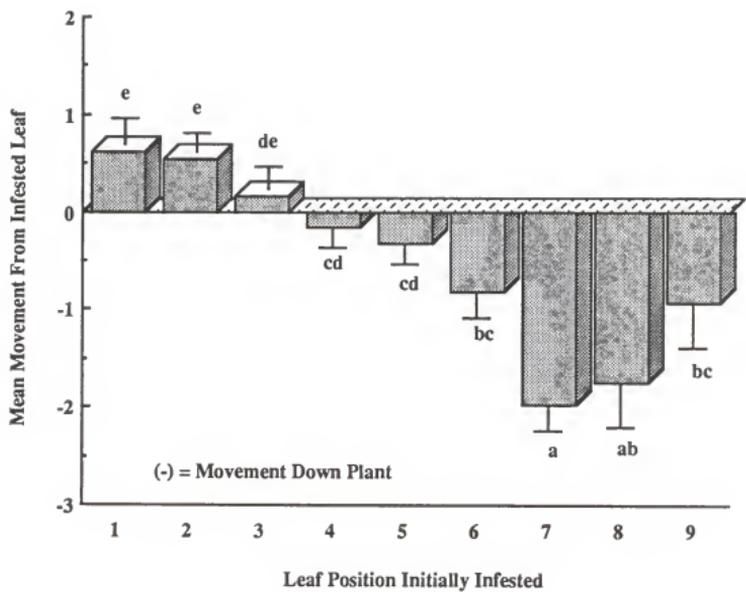


**Table 5. Mean Movement of BGM From Initially Infested Leaf. 1988.**

Leaf Position Initially Infested	Mean Mvt.	Std. Err	P-value
1	.62 e	.26	.0220
2	.54 e	.20	.0090
3	.17 de	.24	.4852
4	-.15 cd	.20	.4410
5	-.32 cd	.21	.1351
6	-.81 bc	.26	.0029
7	-1.98 ab	.26	.0001
8	-1.74 ab	.46	.0002
9	-.92 bc	.46	.0455

- \* Means are least square means.
- \* P-value, Probability values. Probability values less than 0.05 indicate movement significantly different from zero.
- \* Means followed by the same letter within a column are not significantly different.
- \* (-) signifies movement down plant from infested leaf.

Figure 4. Mean movement of BGM from initially infested leaf. Pooled data, 1988. Means are least squares means. Means followed by the same letter are not significantly different.



PART II

VERTICAL DISTRIBUTION OF ADULT FEMALE BANKS GRASS  
MITE, OLIGONYCHUS PRATENSIS (BANKS), FECUNDITY  
ON CORN, ZEA MAYS L.

#### ABSTRACT

Fecundity of the Banks grass mite, Oligonychus pratensis (Banks) was studied in relation to the vertical position of leaves on corn Zea mays L. Our hypothesis was that fecundity would be negatively associated with the propensity of adult female mites to move from a leaf. The fecundity of individual 1 day old mites was tested on corn at leaf positions 1-9, starting from the bottom-most leaf that was at least 1/3 green. Egg counts were made every 2 days and continued throughout the mites reproductive lives. Tests were conducted in the field and greenhouse on whorl and tassele stage corn. No distinguishable pattern of BGM fecundity was found to be associated with leaf position, and the data did not support the hypothesis that fecundity would be negatively associated with the propensity of mites to move from a leaf.

The distribution of mites on a corn plant may be a factor of internal and external cues that elicit responses in a mite to either stay put or disperse to a new location. Suggestions as to what cues may contribute to a mites "decision" to stay or go are discussed.

## Introduction

In Kansas and other regions of the Western Great Plains, the Banks grass mite (BGM), Oligonychus pratensis (Banks) is a serious pest of wheat, sorghum, and corn (Ward et al. 1972, Owens et al. 1976). This mite is characterized by sporadic outbreaks and rapid population increases. A combination of host plant conditions (stressed plants) and weather (hot and dry) are important factors in causing these outbreaks (Perring et al. 1982,1983).

Past research on the Banks grass mite has been done to determine basic life history parameters in order to understand the population dynamics and how they relate to the movement or dispersal of this pest into crops (Toole et al. 1984, Perring et al. 1984ab, Feese and Wilde 1977, Tan and Ward 1977, Mitchell 1970).

Researchers have also looked at how BGM disperses within a single field and within a single plant (Pickett and Gilstrap 1986; Gilstrap et al. 1980; Archer and Bynum 1986), but little conclusive data exists to explain the ecological basis behind the dispersal strategies employed by the Banks grass mite.

The habitat of BGM in the system with which I work, is ephemeral, lasting only during the growing season. To increase the chance of survival throughout the season, spider mites have evolved a relationship between

survival, reproduction, and dispersal or the ability to locate new resources so that they can survive and reproduce in these ephemeral habitats. According to Wrench and Young (1978), females disperse from locations on a plant with high mite densities and heavy leaf damage to less-populated portions of the plant to establish new colonies. But, how or why dispersing females chose one new colony location over another is still unknown.

Studies have been done on various crop plants, such as corn and sorghum, to determine if components (such as sugars, or nitrogen and phosphorous compounds) or changes in these plant components over time are the basis for various dispersal behaviors in mites (Perring et al. 1983, 1982). Perring et al. (1983) suggested that the alteration of nutrient concentrations in the leaves of a maturing plant may either increase or decrease its value as a spider mite food resource (ex. in sorghum, increases in concentrations of soluble carbohydrates decreased a leaf's suitability as a food source).

This would lead one to question whether a certain stage or age of plant is a better host. Perring et al. (1982) suggested that a senescing plant, with stressed leaves because of translocation of nutrients to the filling grain, was an important factor in spider mite increases. Feese and Wilde (1977) noted that fecundity

was greater in silking than on seedling corn. They suggested that nutrients in the leaf tissue during silking may fulfill the mite's nutrient requirements more adequately than when plants are in the seedling stage.

In 1980, Gilstrap et al. studied within-plant distribution of BGM on corn . Their results showed that mites were aggregated on the bottom portions (bottom-most leaf= leaf position 1) of all plants, usually with a decisive peak at leaf positions 3, 4, 5, or 6. They found that at least 75% of the total number of female mites/plant were located on leaf positions 1-7. Archer and Bynum (1986) studied BGM distribution on sorghum. They suggested, for sorghum, that the differences in mite distribution appeared to be influenced strongly by the number of leaves per plant. Mites were found near the bottom of the plants with the fewest leaves and in the middle of plants with the most leaves. Most BGM were located on leaves in the lower 2/3 of the plant.

In our previous study on the within-plant vertical distribution of BGM on corn, mites artificially infested upon various leaf positions of a corn plant would: 1) Move down the plant when infested upon upper leaf positions. 2) Move up the plant slightly when placed upon leaf positions one and two. 3) Showed a tendency not to move off of leaf position three and four when

infested upon that leaf.

This study was conducted to determine if BGM would be most fecund on the areas of the corn plant that were most "preferred", or that they occupy most often.

Our hypothesis was that fecundity would be negatively associated with the propensity of adult female BGM to move from a leaf.

## Methods and Materials

The Banks grass mites used in this experiment were all from a 3.5 year old laboratory colony maintained on corn seedlings at a photoperiod of 14:10, a relative humidity between 38-45%, and a temperature range of 80-87 F.

Female BGM were collected as quiescent deutonymphs. This is the last immature stage before mites molt to adult. As this stage is dormant, collection is relatively easy. All replicates were started with a cohort (100-200) of day-one adult females. Females were assumed to have mated as mating usually occurs immediately after ecdysis to an adult. (Potter et al. 1976).

The fecundity of individual spider mites was tested on corn leaves at leaf positions 1-9. Leaf position one was defined as the bottom-most leaf that was 1/3 green (Gilstrap et al. 1980). No mites were caged on leaves above leaf position 9, because < 25% are found above this leaf position (Gilstrap et al. 1980; Archer and Bynum 1986). Mites were caged individually, 1 mite per leaf. Mites were caged on the undersides of corn leaves by one of two types of clip-on adhesive cages. The first type of cage was constructed from Scotch brand double-sided, adhesive mounting squares. An individual square was made into four cages by punching holes with a

standard hand-held hole punch, so that each cage was approximately 1.5 x 1.5 cm. with an inside diameter of .6 cm. One side of the adhesive protective backing was removed and a very fine organdy netting was stuck to the cage. Netting was used for ventilation and enclosure of cage. The other adhesive backing was removed, mites were placed in the cages by means of a triple 0 camel-hair brush and the cage adhesively stuck to the leaf. Further anchorage to the leaf was found to be needed as the adhesive on the mounting squares was not adequate under windy field conditions. This was accomplished by means of double-pronged hair clips. The second type of cage was made from a similar product (Tape Shapes by Converters Inc, 2671-73 Salmon Street., Philidelphia, PA 19125 makes double-sided adhesive forms to order).

**Laboratory Tests** Two replications were preformed in a temperature-humidity controlled rearing room. Space limitations allowed only four plants to be tested per replication. Plants used for rearing room reps. were grown in large plastic pots using a sterilized soil-vermiculite mixture. Plants were raised in the greenhouse under a 14:10 photoperiod until they reached the 5-8 leaf stage. Upon this stage, plants were moved into the rearing room for testing. Temperatures in rearing room ranged from 23-27 C and humidity was between 30-40%

**Field Tests** Five replications were conducted in the field, with 9-10 plants per replicate. Field work in this experiment was conducted on research plots located by Tuttle Creek in Pottawatomie County, Kansas. There were four different plots of Pioneer 3377 grown, and each plot had a different planting date ( 5/12/88, 6/6/88, 6/23/88, and 7/13/88). Separate dates allowed corn of varying ages to be used throughout the growing season. Standard agronomic practices were used to plant the corn, and plants were irrigated when needed.

Mites lost due to predation, or in transfer to new cages were replaced from same-aged females from the cohort. After data was collected, a preliminary analysis was done to determine if the few mites used that were older than day 1 affected the results. Age was not found to be a factor in this study (less than 20% of mites used were older than day one). Mites from the cohort not presently employed in the field were kept on detached leaf sections. These leaf sections were kept moist on damp cotton and replaced as needed.

BGM egg counts were taken every two days. Preliminary tests showed that counts made every day resulted in a high loss of mites in transfer to new cages, and counts made after 3 or more days allowed eggs to hatch and excessive feeding damage to leaf surface. Eggs were counted with a 10-X hand-held magnifying lens.

Mite cages were removed from the leaf in order to make the egg counts. Eggs were not visible through the organdy netting. Mites were transferred to new cages after each counting episode. Each new cage was placed on a new position on the same leaf. Cages were placed as close to midribs as possible. All cages were started close to the stalk, moving distally for each new cage area after an egg count. Used cages were labeled and returned to lab so that eggs laid in them could be counted with help of a stereo scope. Greenhouse and field data were analyzed separately. Field data was analyzed by growth stage, and then pooled.

A randomized complete block design was employed. A GLM F-test was used to analyse all data except for replicates that were done on tasseling corn, this because of small sample sizes. GLM was used to adjust means for unequal sample sizes. Independent variable was leaf position and the dependent variable was the average fecundity. An LSD T-test was used to analyze tassel stage corn, dependent variable was the average fecundity and the independent variable was the leaf position.

After the data were analysed, it appeared possible that an alternate leaf effect may have been present. Data were re-analysed by combining alternate leaves of the plant to separate the vertical response of fecundity from any possible alternate leaf response.

## Results

**Greenhouse Tests** Data from the two greenhouse whorl stage corn replicates were pooled since both were on the same stage corn and individual sample sizes were not large. Fecundity on leaf position 3 was significantly lower at 5% level than all other leaf positions (Figure 5, Table 6).

**Field Tests** When field data on whorl stage and tasseling corn replicates were pooled, P was significant at the 5% level, but no differences were found between fecundities on the various leaf positions. (Table 7, Figure 6).

In the analysis of field data by corn growth stage, whorl and tassel (Tables 8-9, Figures 7-8), P was not significant at the 5% level in either stage. In tasseling corn, reduced sample sizes allowed only protected LSD means to be calculated.

## Discussion

Results in most cases were not significant, and no vertical pattern of fecundity was apparent. Findings from my previous study found that mites artificially infested upon leaf position 3 and 4 showed a tendency not to move off of those positions. That seemed to suggest, for some reason, that certain areas of the plant are "preferred" or that others are less favored.

It was believed that conditions (microenvironmental, nutritional, or other) that might increase the fecundity of BGM may have been responsible for the tendency of mites not to move from certain areas. In this study, the vertical distribution of BGM fecundity did not align itself to the hypothesis that fecundity would be negatively associated with the propensity of adult females to move from a leaf. The vertical distribution of BGM fecundities did not reflect the pattern of movement or distribution that was found in our previous study.

It may be that the cues mites respond to involving dispersal from an area override cues that involve an area's quality as an ovipositional site. There may be a delicate balance existing between any cues stimulating mites to stay and oviposit vs to spread the risk of survival by dispersing to a new location. If there is the option of an increased fecundity by staying put or an increased survival by moving, which way the balance falls is probably genetically programmed. Over time, this programming was probably determined by internal cues of the reproductive states and external cues of microenvironment and host plant conditions of past generations of BGM.

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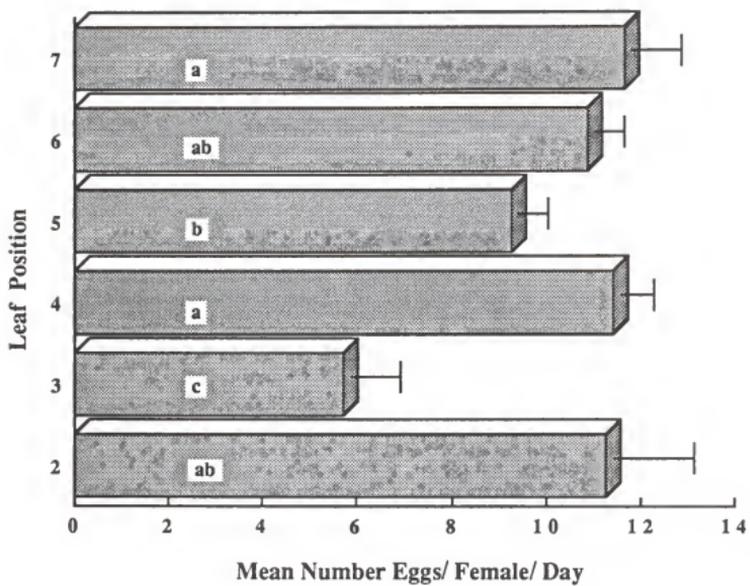
**Table 6. Mean Daily Fecundity of BGM  
on Whorl Stage Corn in the  
Greenhouse.**

Leaf Position	Mean	Std. Error
2	11.28 ab	1.69
3	5.72 c	1.04
4	11.43 a	.69
5	9.28 b	.61
6	10.87 ab	.64
7	11.65 a	1.04

\* Means are least square means.

\* Means followed by the same letter within a column are not significantly different.

Figure 5. Vertical distribution of BGM fecundity on whorl stage corn in the greenhouse. Means are least squares means. Means followed by the same letter are not significantly different.



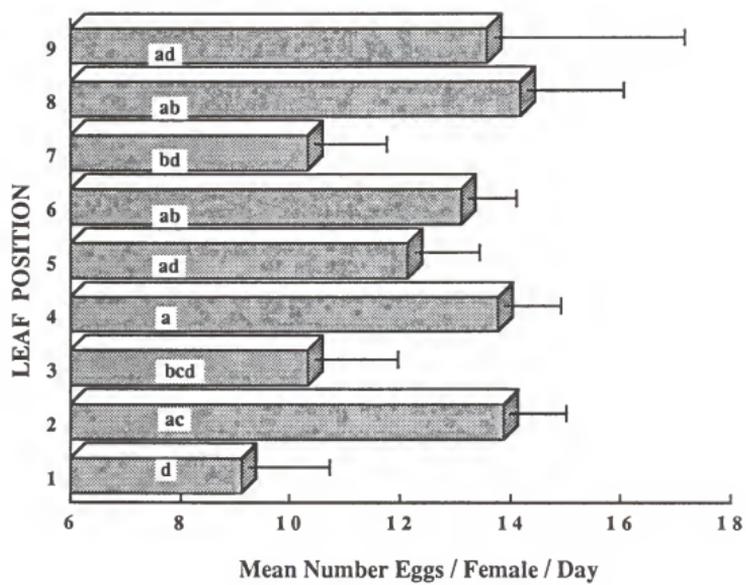
**Table 7. Mean Daily Fecundity of BGM on Whorl and Tassel Stage Corn in the Field.**

Leaf Position	Mean	Std. Err.
1	9.12 d	1.47
2	13.89 ac	.98
3	10.33 bcd	1.51
4	13.79 a	1.01
5	12.13 ad	1.19
6	13.12 ab	.87
7	10.33 bd	1.32
8	14.18 ab	1.74
9	13.59 ad	3.43

\* Means are least square means.

\* Means followed by the same letter within a column are not significantly different.

Figure 6. Vertical distribution of BGM fecundity on whorl and tassel stage corn in the field. Means are least squares means. Means followed by the same letter are not significantly different.



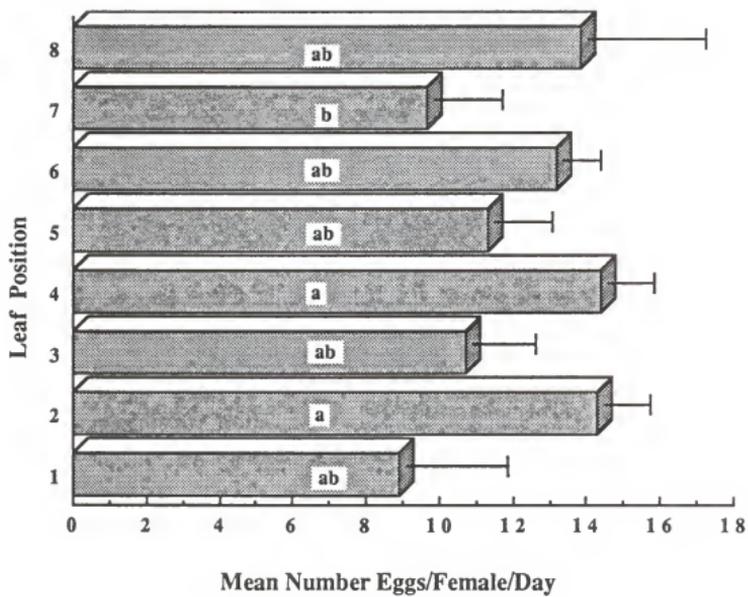
**Table 8. Mean Daily Fecundity of BGM  
on Whorl Stage Corn in the Field.**

Leaf Position	Mean	Std. Err.
1	8.91 ab	2.77
2	14.27 a	1.29
3	10.71 ab	1.73
4	14.38 a	1.25
5	11.33 ab	1.56
6	13.15 ab	1.02
7	9.63 b	1.86
8	13.85 ab	3.18

\*Means are least square means.

\*Means followed by same letter within a column  
are not significantly different.

Figure 7. Vertical distribution of BGM fecundity on whorl stage corn in the field. Means are least squares means. Means followed by the same letter are not significantly different.



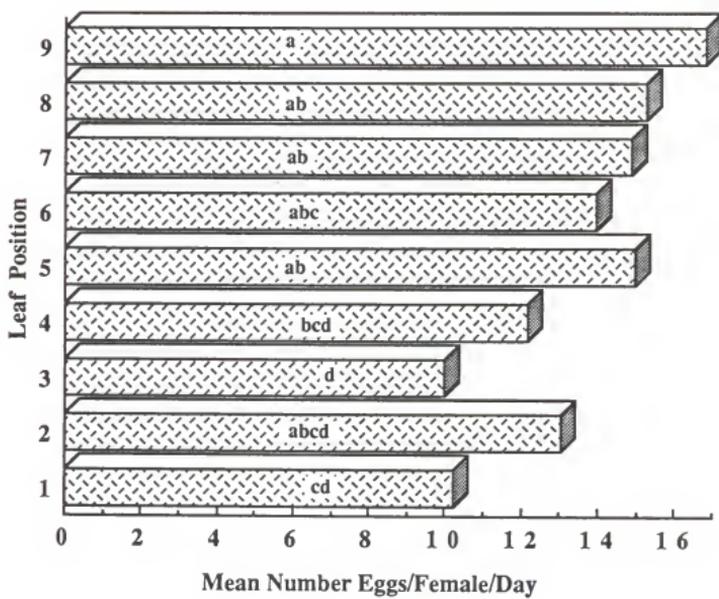
**Table 9. Mean Daily Fecundity of BGM  
on Tassel Stage Corn in the Field.**

<b>Leaf Position</b>	<b>Mean Fecundity</b>
1	10.21 cd
2	13.01 abcd
3	9.96 d
4	12.17 bcd
5	14.98 ab
6	13.96 abc
7	14.85 ab
8	15.24 ab
9	16.80 a

\* Means are LSD means.

\* Means followed by same letter within a column are not significantly different.

Figure 8. Vertical Distribution of BGM Fecundity on Tassel Stage Corn in the Field. Means are LSD means. Means followed by the same letter are not significantly different.



## Summary and Conclusions

A study was conducted to determine the vertical within-plant dispersal of adult female Banks grass mites on corn, and to determine factors that might contribute to or influence this distribution.

In this study it was found that BGM artificially infested upon leaf positions 1-9 of a corn plant would: 1) move up the plant slightly when infested upon leaf positions 1 and 2, 2) move down the plant when infested upon leaf positions 5-9, and 3) tended not to move off of leaf positions 3 and 4 when infested upon those positions. Growth stage of the plant (whorl and tassel) was determined by analysis not to affect the distribution of BGM in this study. The results seemed to suggest that certain areas of the plant were "preferred" or that others were less favored. As the combined effects of fecundity and survival of progeny determine population growth of a colony, it was decided to conduct a fecundity test on the various leaf positions of a corn plant. It was hypothesized that fecundity would be negatively associated with the propensity of adult mites to move from a leaf.

The fecundity of individual adult female mites was tested upon leaf positions 1-9 on whorl stage and tasseling corn. There were few significant differences in fecundity upon leaf positions, and no overall pattern

was apparent in the tests. Our data did not support our hypothesis that fecundity would be negatively associated with the propensity of adult female BGM to move from a leaf.

In conclusion, it was found that BGM do not necessarily stay on the first site encountered of a host plant, but what elicits dispersal is not known. It is felt, that internal and external cues, genetically programmed from the experiences of past generations, determine whether BGM stays where it is or disperses to a new location. Factors such as microenvironment, host plant condition and reproductive state of the mite may be cues that elicit a response from BGM.

Future studies by researchers should be conducted to determine survival and growth of juvenile BGM on the various leaf positions of corn in a field situation. Also, studies should be conducted to determine the key factors that influence survival. Factors such as predation by natural enemies, nutrition, and microenvironmental aspects such as wind, temperature, canopy coverage, and humidity. Studies such as those conducted by the author and by those in the future are needed to gather basic life history parameters on pests such as the Banks grass mite. Data on basic life history parameters are the stepping stones used for developing integrated control measures and computer modeling systems for various agricultural and ornamental

pests.

VERTICAL WITHIN-PLANT DISPERSAL OF BANKS GRASS  
MITE OLIGONYCHUS PRATENSIS (BANKS) (ACARI:  
TETRANYCHIDAE), ON CORN ZEA MAYS L.

by

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### Abstract

Studies were conducted to determine the vertical within-plant dispersal and the vertical distribution of fecundity of the Banks grass mite, Oligonychus pratensis (Banks), on field corn Zea mays under field and greenhouse conditions.

Adult female BGM were placed on corn plants at leaf positions 1-9, starting from the bottom-most leaf 1/3 green. Density levels of 25, 50, and 100 were employed in 1986-87 while levels of 50, 100, and 200 were used in 1988. One to 3 days later, leaves were cut off the plants one at a time and the number of mites on each leaf was determined. Changes in mite distribution were utilized as an indirect measurement of mite movement on the plants.

Percentage of mites recovered was low (10 to 50%). Density effects were present in 1986-87 data, and were probably a factor of low initial density used. No density effects were found in 1988 when density levels were increased.

Mite dispersal followed a consistent pattern in the two data sets. Adult female BGM were found to 1) move up the plant slightly when infested upon leaf positions 1 and 2, 2) move down the plant when infested upon leaf positions 5-9, and 3) tended not to move off of leaf positions 3 and 4 when infested upon those positions. Growth stage of corn (whorl and tassel) did not affect

distribution of BGM in this study.

Further studies were conducted to determine if BGM's pattern of distribution could be associated with differences in mite fecundity on different parts of the plant. The hypothesis was that fecundity would be negatively associated with the propensity of adult mites to move from a leaf. The fecundity of individual adult female mites was tested on corn leaf positions 1-9. Mites were confined to the undersides of leaves by adhesive clip-on cages. Egg counts were started with day 1 adult females and continued throughout their reproductive life. Tests were conducted in the field and greenhouse on whorl and tassel stage corn. There was no distinguishable pattern in BGM fecundity on different parts of the plant. Our hypothesis that movement might be associated with fecundity was not substantiated.

It was found that BGM artificially infested upon various leaf positions of a corn plant would disperse, and therefore BGM does not necessarily stay on the first site of a host plant that is encountered. Suggestions as to what factors may contribute to a mites "decision" to stay in an area vs disperse are discussed.