AGRONOMIC FIELD OBSERVATIONS RELATING TO MITE DEVELOPMENT ON CORN IN SOUTHWEST KANSAS

by

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B. S., Kansas State University, 1965

A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1975

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

One of the most complexing problems to corn growers in Southwest Kansas is the seasonal invasion of spider mites into irrigated field corn. Three species have been identified and related to damage on field corn in the area. The three species of spider mites include the Banks grass mite, _Oligonychus pratensis_ (Banks); twospotted spider mite, _Tetranychus urticae_ Koch and the carmine spider mite, _Tetranychus cinnabarinus_ (Boisduval). Of the three species the Banks grass mite and the twospotted spider mite are the most predominant with the carmine spider mite only recently identified and related to damage on corn.

The severity of the problem has caused alarm among the growers in the Southwest Kansas area. Lack of knowledge of the physiology of corn as it relates to mite development and the intricate biological potential of the three species of spider mite poses a complicated control situation. These obstacles have prevented adequate determination of needed preventive control measures and the evaluation of economic thresholds of infestations which may be tolerated before chemical treatment is applied on corn fields. Continuous infestations during the growing season, particularly in the later maturity stages of corn, have aroused a demand for information that will allow growers to apply chemical or biological control measures to fields for maximum production.

Occurrence of spider mite damage on corn has progressively increased in counties which have extensive irrigated corn acreage.

Reports of mites on corn have been recorded in various parts of Kansas. However, the major infestations center in areas of low rainfall, low humidity and seasonal high temperatures. These conditions are typical of the Southwest region of Kansas. In addition, the corn acreage under irrigation has increased significantly in the past five years in the area. Both factors, extensive corn acreage and optimum climatic conditions, enhance the spider mites' effect on production in Southwest Kansas.

The problem of spider mite infestations is not entirely limited to Kansas corn alone. The lower Rio Grande Valley of Texas, the Arkansas Valley in Eastern Colorado, the Central California region, and, more recently, the western portion of Nebraska have all encountered mite infestations in areas of dent corn production. Areas in Arizona, Idaho, New Mexico, Florida, and Washington have also reported damage on corn. The most severe infestations, however, involve areas of low moisture potential and regions affected by drought.

All three species of the spider mites or a combination of species have been identified in the various geographical areas of corn production under moisture stress conditions. In dealing with the spider mite problem, considerations must be made for the three species when assessing damage since they have reportedly been found within the same field (Bell, 1972). This further compounds the problem since the biological relationships of the three species and their effect on field corn must be evaluated together when determining control practices and conducting research. Practical investigations to reduce spider mites must consider the Banks grass mite, twospotted spider mite and the carmine spider mite as a unit of infestation.

In 1973, a USDA/Cooperative Extension Service pest management pilot program was initiated in three southwestern Kansas counties to aid growers in determining levels of insect infestation on sorghum and corn, and to determine practical control measures for the populations present. Included in the program were observations and recordings of damage levels caused by mites throughout the corn's development. The field observations utilized in this study were from Haskell County. The county was selected because it is the leading county in corn production in the State of Kansas with a recorded 97,920 acres. All acres were under either flood or sprinkler irrigation. This study revolved around spider mite infestations on 5,477 acres of irrigated corn selected from the pest management program in Haskell County.

ECONOMIC IMPORTANCE OF THE STUDY

Corn has rapidly gained prominence in Southwest Kansas agriculture during the last ten years. In 1964 the Southwest area harvested 43,300 acres of corn (Farm Facts, 1964-1965). The last recorded harvest in 1974 showed an increase of irrigated acres to 518,500. This tremendous advance has resulted from increased development of irrigated acres and conversions from sorghum grain and other crops to corn. In Haskell County, the county selected for field observations, the corn acreage in 1964 was 4,000 acres. Records in 1974 showed the county increasing to 97,600 acres of corn, according to Farm Facts (1973-74).

The increased supply of corn has generated additional industry in the 14 counties composing the Southwest Kansas reporting district. Beef cattle feeding has jumped from 95,140 grain fed cattle in 1964 to 833,100 head fed in 1974 (Farm Facts, 1964-65; Farm Facts, 1973-74). Corn production in Haskell County has encouraged the establishment of 8 commercial feedlots with a total capacity of 131,000 head of cattle. In the feedlots of the district, corn represents a major portion of the rations and a reduction of the supply would generate a major curtailment in cattle feeding activities.

Corn production has created a complex of storage facilities which links Southwestern Kansas with the grain trade. The elevators have increased storage capacity to accommodate large corn acreages and are now in turn highly dependent on the continuous production of that acreage.

According to the Kansas Cooperative Economic Insect Survey Reports, no large acreage infestation of spider mites occurred until 1968 and 1969 (K. O. Bell, Jr., personal communication, 1974. Survey Entomologist for State of Kansas, Topeka). Acres of corn damaged from mites have progressively increased from 1968 in conjunction with increased corn acreage. One exception to the trend was in 1972 as indicated in Table 1. The rainfall for 1972 was unusually high for the area during that summer with accompanying cool weather. It is apparent from Table 1 that spider mite infestations are increasing in Southwest Kansas. Certainly one can expect phytophagous insect infestations to increase as the acres of host plants increase. However, the increase in proportion of damaged acres to total acres is noticeable. In 1968 only 19.9 per cent of the total acres were damaged. This ratio increased to 48.8 per cent of the total corn crop in 1974. Some variation may be due to reporting procedure. However, the difference in percentage of corn damaged in 1974 was large enough to warrant concern for the corn growers in the Southwest District.

Table 1. Spider mite damaged and treated corn acres as compared to total corn in Southwestern Kansas.

Year	Damaged Acres[1/]	Treated Acres[1/]	Total Acres Harvested[2/]
1968	30,000	12,000	150,000
1969	33,000	33,500	222,090
1970	59,950	56,210	281,000
1971	66,000	62,450	307,370
1972	10,500	8,000	317,590
1973	75,000	129,200	459,500
1974	253,350	314,200	518,500

1/ Data derived from Kansas Farm Facts, 1968-74. State Board of Agriculture, State Printing Office, Topeka, Kansas.

2/ Data derived from Kansas Cooperative Insect Surveys, 1968-74. State Printing Office, Topeka, Kansas.

The reports indicate that 314,200 acres in the Southwest Kansas area were treated for spider mite infestations in 1974 (Bell, 1974). Surveys of the Division of Entomology in Kansas assess the average cost of spraying to be four dollars an acre for 1974. Using this value, the cost to southwestern Kansas corn growers of treating spider mites was estimated at 1,256,800 dollars. This figure represents 1.2

per cent of the net value placed on the corn crop in the area. Many growers involved in the study reported two treatments to corn acreage during the 1974 crop season, which would further increase their production costs.

One of the most important factors in the economics of corn production under spider mite infestations is the determination of actual need for treatment. No investigations have established an economic threshold of infestation. Examination of Table 1 reveals that in the earlier years, acres treated lagged behind acres damaged. As awareness of the mite increased, acres treated soon increased above acres damaged. No dollar loss can be directly assessed to spider mite damage. However, severe mite feeding causes noticeable desiccation of corn leaves and explains the desire of the growers to treat infested acres.

LITERATURE REVIEW

History of Agronomic Infestation by Mites

Agronomic damage by spider mites on corn was first reported by Walter (1956) in Weslaco, Texas. Identification was made by E. W. Baker of the Entomology branch of the Texas Research Station to be *Oligonychus pratensis* (Banks). Only obscure reportings of spider mites on corn were made prior to that time with no reference to damage or identification of the species. The first recorded observation of spider mites on corn in Kansas was in southwestern Kansas. Infestations were determined by DePew (1960) to be both the twospotted spider mite, Tetranychus urticae Koch and the Banks grass mite, Oligonychus pratensis (Banks). No mention had been made of the carmine spider mite, Tetranychus cinnabarinus (Boisduval) on corn in Kansas or other states until it was identified in Stevens County in Southwest Kansas in 1971 (Bell, 1971).

Independent discussion of histories of each of the three species of mites is necessary to indicate the species' significance in literature.

Twospotted Mite, Tetranychus urticae (Koch): The history of the twospotted spider mite is prominent in literature throughout the country. Early mention of this species on major feed and fiber crops has been made by numerous authors. Some confusion is evident as to the taxonomic status of the mite. History of the mite is interspersed between the taxonomical classification of the earlier identification of Tetranychus telarius (Linnaeus) and Tetranychus urticae Koch, with the T. urticae being the most recent classification used (Boudreaux, 1956). Further complexities in the literature involve some confusion between Tetranychus cinnabarinus (Boisduval) and Tetranychus bimaculatus with T. urticae (van de Vrie, McMurtry and Huffaker, 1972). Regardless of the taxonomic problems, T. urticae has been well documented as a pest on various field crops.

References to other serious twospotted spider mite infestations on corn were first made in Washington (Klostermeyer, 1961), California (Bacon et al., 1962), and Colorado (Schweissing, 1964). Southwest Kansas received the first heavy population concentrations in corn in

1965 (DePew, 1965). The Kansas and California observations referred to the Banks grass mite as being present in conjunction with twospotted spider mite populations. Since then both species have continued to increase and spread in corn. Presently populations of *T. urticae* have been found in areas of high infestations of spider mites in Southwest Kansas (J. D. Stone, personal communication, 1974. Research Entomologist, Garden City Experiment Station, Garden City, Kansas).

Banks Grass Mite, *Oligonychus pratensis* (Banks): Definite identification of the Banks grass mite was first documented by Banks (1914) on timothy near Pullman, Washington. The mite was then named *Tetranychus pratensis*. Later in 1939 the mite was identified on date palms; and, finally, in 1960 the Entomological Society of America renamed the mite *Oligonychus pratensis* (Banks) (Elmer, 1965).

The Banks grass mite has been collected from many grass types including cereals, forage grasses and sugar cane since 1950 (Elmer, 1965). It continued to infest areas of agricultural production in the states of Washington, California, Arizona, New Mexico, Texas, Colorado, Kansas, Idaho, Montana, Virginia and Florida (Malcomb, 1954). The spread of the mite to grain crops in the central area of the United States began in 1952 with Harvey (1954) describing the pest's effects on wheat in Eastern New Mexico. In 1952, Griffith and Wene (1953), identified the spider mite on grain sorghum near San Manuel, Texas.

The first report of the mite on corn came from Walter (1956) in the lower Rio Grande Valley. Reports intensified on the occurrence of Banks grass mite in corn following 1960. DePew (1960) first reported

Banks grass mite in Kansas on wheat in the southwestern region in 1960. He further verified its presence on corn and sorghum in Kansas. The pest has been identified in damaging proportions in Colorado corn fields and recently became an economic threat to Nebraska (Hagen, 1973). According to Cooperative Insect Survey Reports in Kansas, the Banks grass mite continues to increase in numbers each year in the Southwest (Bell, 1973-74).

Carmine Spider Mite, Tetranychus cinnabarinus (Boisduval): Little reference to the carmine spider mite is made in the literature concerning its effect on plant hosts. Until recently this species was often treated as Tetranychus urticae which may account for the lack of information on the mite. Boudreaux (1956) differentiated between the carmine spider mite and other species, providing an index for positive identification for further reference. He confirmed the presence of the species in the United States in 1950.

No record is available of the carmine spider mite contributing to infestations on grain crops between 1950 and 1960. The first positive identification was confirmed in Kansas on corn during 1971 by W. R. Enns, entomologist at the University of Missouri as reported by Bell (1971), who observed the mite on corn in Stevens county in southwestern Kansas. The carmine spider mite was found on the same leaves as twospotted spider mites.

Since 1971 reports of the spider mite have been made on corn in Southwest Kansas but few confirmations have been established. The extent of infestation of carmine spider mites in corn remains questionable.

Prospects of future problems with this mite is possible and may evolve into an economic consideration in corn.

Physiological Corn Relationships to the Biological Potential of the Spider Mite

Consideration must be made for determining the relationship between host and parasite when attempting to ascertain adequate control programs. The biological potentials of the three species of corn-infesting spider mites are important parameters when their impact on the physiology of corn is considered. Some generalizations may be made between the species. However, separate discussions are necessary in certain biological areas of the tribe Tetranychini in order to evaluate control programs.

Biology of the Twospotted Spider Mite, *Tetranychus urticae* Koch

The life cycles of the twospotted mite is a typical epimorphosis with stages being egg, larva, protonymph, deutonymph and adult (van de Vrie et al., 1972). All three immature stages are followed by quiescent stages: nymphochrysalis, deutochrysalis and teleiochrysalis, respectively. Differences in development rates between sexes are notable. Early maturing males locate and remain near the females in teleiochrysalis until the females hatch. Copulation occurs almost immediately after the females hatch, which explains why investigators find that in a normal bisexual population, the females are nearly always mated (Mitchell, 1973; Lehr and Smith, 1957; van de Vrie et al., 1972). Unfertilized eggs produce only males, fertilized ones, only females.

But mated females may produce both sexes, because not all eggs receive spermatozoa.

Rate of development of each growth stage and egg production are parameters of the life cycle which may be altered by host environment (van de Vrie et al., 1972). The rate of development of the immature stages is influenced by temperature, humidity and quality of food. Paralleling development rates, the oviposition rate of females is determined by nutrition, temperature, humidity, and possibly photoperiod (van de Vrie et al., 1972). Under optimum conditions the females can lay up to 20 eggs a day; however, the average for the species is 5 to 6. One mating supplies the female with enough sperm for life. According to Mitchell (1973) development from egg to egg requires about 19 days, but females do not reach full size until the 24th day. The development of the egg takes 7 days after the egg is laid. Lehr and Smith (1957) found the average oviposition period of _T. urticae_ and _T. cinnabarinus_ to be 14 to 15 days, giving the mite a potential of laying 90 to 100 eggs during its life span.

Injury to host plants by the twospotted spider mite is caused by the piercing and withdrawal action of their stylets (van de Vrie et al., 1972). Damage to protective leaf surfaces, palisade and spongy parenchyma cells, and disruption of stomata guard cells all cause excessive loss of water (Henneberry, 1964). Loss of chlorophyll and corresponding loss of photosynthetic potential add to the spider mites' reduction of total yield in many host plants (Mitchell, 1973; Avery and Briggs, 1968). Most investigators agree the loss of water and leaf cells by rasping action of spider mites represent the only damage potential. However, Leigh (1963) suggests that a toxic substance injected into the plant by the spider mite causes additional damage. Observations of damage to corn, made in the field, lend support to the cell damage concept caused by feeding with no indications of toxic substances involved (Schweissing, 1964). Corn plants under observation by Bacon, Lyons and Baskett (1962) were desiccated by feeding which further led to physiological damage in terms of decreased ear size and stalk strength.

Movement and dispersion of twospotted spider mites on their host plants and between fields has been well documented by researchers. Extensive work by Mitchell (1973) shows that female mites obtain maximum dispersal activity when they are crowded and host resources are poor. Females emerge at less than half their full size and, after mating, disperse without feeding to other areas. Males do not migrate with them, according to studies of Hussey and Parr (1963). The dispersing female spins silk and feeds within a restricted area, normally adjacent to major veins, which can explain the initial development of mites on a corn leaf along the mid-rib. Young mites remain in the circumscribed area, thus developing family territories.

Direction of movement by females migrating from crowded areas has been upwards and towards light (Hussey and Parr, 1963; Mitchell, 1973). Most upward movement was accomplished from leaf to leaf; however, plant to plant movement resulting from massing of mites at the tips of leaves and subsequent spinning down to the ground was noted by Boyle (1957).

After arriving on the ground or lower leaves, the mites again followed the pattern of moving up and to the light on other plants. This phenomenon can well explain the infestation pattern of mites on corn. The spider mite begins on the lowest leaf and moves upward on the plant as populations increase.

Field-to-field dispersal of twospotted spider mites have been investigated by Feschner, Badgely, Ricker and Hall (1950) and Boyle (1957). Normal dissemination of mites was by upward drifting on air currents and lateral movement in the direction of prevailing winds. The ballooning effect of silk threads aiding in the upwards drift has been dispelled by investigators for this particular species (Boyle, 1957).

There seems to be no doubt among the many investigators that *Tetranychus urticae* is one of the most polyphagous species of the family Tetranychidae with a long list of host plants. According to van de Vrie et al. (1972) the constantly growing list includes diverse families of the plant kingdom as indicated in Table 2.

Table 2. Common plant hosts of the twospotted spider mite, *Tetranychus urticae* Koch.

Vegetables	Fruits	Ornamentals	Field Crops	Weeds
Tomatoes	Strawberry	Carnation	Cotton	Morning Glory
Bean	Peach	Roses	Sorghum	Field Bindweed
Beets	Apple	Elms	Alfalfa	Ground cherry
Peas	Grapes		Clover	
Cucumbers	Raspberry		Hops	
	Pear		Soybean	

The table represents only a small percentage of the hosts of this diversified species. In the literature of the twospotted spider mite, little reference is made to corn as a host. A complete review made by van de Vrie et al. (1972) makes no mention of the recent infestations of the species in corn. Problems in proper identification of the mite and separation from the Banks grass mite explain deletion of the species from reviews.

General observations of various host plants reveal that different plant species or varieties present different increase potentials for the T. urticae (van de Vrie et al., 1972). This relationship to the physiological makeup of the host may influence fecundity, egg viability, and mortality and rate of development of the immature stages. Stoner and Stringfellow (1967) demonstrated the differences in reproduction of mites as compared to various varieties of tomatoes.

Attention to alternate host plants is important in considering a total control program. The ability of adult females to overwinter in the diapause stage on alternate host plants adds another dimension to control attempts (van de Vrie, 1972). Many weeds serve as host to the twospotted spider mite, which would hinder any attempt to total clean-up. The presence or absence of adequate weed hosts could influence rate of development and dispersion the following growing season in corn or other cultivated crops.

Biology of the Carmine Spider Mite, *Tetranychus cinnabarinus* (Boisduval)

Differences are minute between the biological traits of *T. cinnabarinus* as compared to *T. urticae*, resulting in some earlier confusion in the literature. Boudreaux (1956) found few morphological differences between the species. He established distinguishing characteristics about color (dark-red) and dorsal lobes. Lehr and Smith (1957) noted that females of *T. urticae* tended to lay their eggs in a smaller area than did *T. cinnabarinus*. No significant differences were noted by these researchers as to oviposition period, number of eggs laid, sex ratio, life span and molt periods. *T. cinnabarinus* did, however, produce fewer viable eggs in the study.

The only documented variation in reproduction of *T. cinnabarinus* from *T. urticae* is that *T. cinnabarinus* does not enter the diapause stage. *T. cinnabarinus* produced the year around in the coastal areas of Southern California (van de Vrie et al., 1972). In addition to constant production, examinations by Boudreaux (1956) found that eggs of the carmine spider mite always had a trace of red as compared to the pale color of the twospotted spider mite.

Dissemination of *T. cinnabarinus* was determined by Boyle (1957) to be similar to that of *T. urticae*. The species is carried by the wind without the effect of "ballooning thread." Since these mites are found within the same leaf area as the twospotted spider mite in Southwestern Kansas, it may be reasonable to assume that the dispersion is similar for both.

Observations have been made that the carmine spider mite favors a more southern temperate zone than does *T. urticae* and plant hosts may vary between the species. Boudreaux (1956) found occurrence of *T. cinnabarinus* limited to warmer latitudes, subtropics and greenhouses. This differentiation may allow a separation of weed hosts since plant species are somewhat limited to temperate zones. However, much similarity exists between the two mite species in relation to life cycle and dispersion patterns on corn and sorghum (Ehler, 1973). The temperature effect may explain why *T. cinnabarinus* is observed in some years in greater numbers than others in Kansas.

Biology of the Banks Grass Mite, *Oligonychus pratensis* (Banks)

Similarities exist between the *O. pratensis* when compared to the life cycles of the *T. urticae* and the *T. cinnabarinus*. Malcomb (1954) in his extensive work with the Banks grass mite discovered that the Banks grass mite differs from the others in that all immature stages are followed by a quiescent period. He found that differences in development rates per stage varied between males and females as did investigators of *T. urticae*. He found that the stadium immature stages differed from generation to generation on barley plants.

Rate of development and egg production were affected in the Malcomb (1954) study by environmental factors including temperature. Malcomb noted the differences between generations but did not specify host or weather conditions at the time of each generation. The average number of eggs produced by the female in all generations was 61.1 for the entire season. Normal production per day was 3 to 4 with the average length of oviposition period being 22.6. The length of incubation stage ranged from 6.1 to 21.5 days for the egg. Larvae, protonymph and deutonymph stages varied in length from 2 to 17 days for both sexes. Total time from hatching to emergence as an adult involves 5 to 37 days for both males and females. Males normally develop in a shorter time. Findings by Elmer (1965), working with this species on the date palm, found the average cycle from egg to adult to be 7 to 15 days. However, he was working under stable room temperatures which may account for the shorter life cycle.

Feeding habits are comparable among the three species of spider mites damaging corn. The O. pratensis feeds by rasping and sucking withdrawal of plant juices and cell chlorophyll. Continuous feeding eventually causes chlorotic symptoms initially followed by browning and complete desiccation of the leaf (Vincent and Lindgren, 1958; Malcomb, 1954). No mention of this species of mites injecting toxic substances into the plant has been made in the literature.

All feeding has been reported on the lower surface of the leaves in corn (Walter, 1956; Ward et al., 1972; Hantsbarger, 1972). Infestations begin on the lower leaves and migrate upwards as populations expand. Most feeding begins along the mid-rib and spreads over the leaf as conditions permit.

Movement of O. pratensis within a field of corn is upwards on the plant in conjunction with feeding habits. No studies have been conducted on light stimulating the direction of movement of Banks grass mite as in the case of the twospotted spider mite. Dispersal from field to field is normally accomplished by drifting on the wind (Malcomb, 1954; Elmer, 1965). Additional dispersal was suggested by the same researchers in the form of movement by attachment to insects, birds, or on particles of debris blown by winds. The mites were deemed incapable of spinning silk strands for the purpose of floating on air currents. Vincent and Lindgren (1958) expressed disagreement with this reporting observations of mites spinning silk and floating off from date palms.

The list of plant hosts of the mite *Oligonychus pratensis* is extensive. However, most plants are limited to the family Gramineae which is in considerable contrast to the wider range of hosts of the *Tetranychus urticae* and *T. cinnabarinus*. Diversification extends from sugar cane in Florida to 'Merian' bluegrass in Washington and johnsongrass in Texas (Malcomb, 1954; Elmer, 1965; Ehler, 1973). Below is a list of plant hosts common to Kansas which represents Malcomb (1954) and Stickney's (1950) list of known plant hosts:

Agropyron desertorum: crested wheatgrass
Agropyron elongatum: tall wheatgrass
Agropyron intermedium: intermediate wheatgrass
Agropyron repens: quackgrass
Agropyron smithii: western wheatgrass
Agrostis alba: redtop
Agrostis palustris: creeping bentgrass
Arrhenathern elatius: tall oatgrass
Bromus arvensis: field brome
Bromus inermis: smooth brome
Cenchus pauciflorus: hairy crabgrass
Digitaria sanguinalis: field sandbur
Elymus canadensis: Canadian wildrye
Elymus triticoides: beardless wildrye
Eragrostis cilianensis: stinkgrass
Festuca arundinacea: tall fescue
Festuca rubra: red fescue
Hordeum jubatum: foxtail barley
Hordeum vulgare: barley
Phalaris arundinacea: reed canarygrass
Phleum pratense: timothy
Poa pratensis: Kentucky bluegrass
Setaria viridis: green bristlegrass
Sorghum halepense: johnsongrass
Sorghum bicolor: grain sorghum
Sporobolus cryptandrus: sand dropseed
Tripsacum dactyloides: eastern gamagrass
Triticum vulgare: wheat
Zea mays: corn

The list is not determined to be complete; however, it does give a perspective to the vast array of plant hosts commonly used by the Banks grass mite in Kansas. Overwintering females and populations in the spring have a wide variety of hosts to build up on prior to the establishment of corn fields during the growing season (Malcomb, 1954; Schweissing, 1973).

In view of the biological similarities between mites, Tetranychus urticae, Tetranychus cinnabarinus and Oligonychus pratensis will be dealt with as a composite in discussions pertaining to physiological relationship of the host.

Physiological Relationship of Plants on Spider Mites

Previous approaches to the physiological relationship of plants and spider mites have been to determine if the insect produced any detrimental reactions in the plant which would be harmful to the total production of the crop. Critical experiments have provided little evidence to support statements on injurious influence of the tetranychids on their host plants due to any type of toxins (van de Vrie et al., 1972). Investigations dealing with physiological attributes of host plants as they affect mites will be reviewed so that this knowledge may be integrated in a practical control program of importance. Most of the studies that deal with the physiological aspects involve affiliations with the plant nutrient supply, plant constituents, leaf age and water stress.

Plant nutrient effects on mite populations have been studied by several investigators. All investigations to date have centered on the reactions of Tetranychus urticae. Predominantly, the research has centered on the plants' ability to absorb nitrogen and the resulting effect on the mite populations. Most results indicate a positive correlation between nitrogen level and mite increase, mainly through fecundity. Garman and Kennedy (1949) published that nearly three times as many T. urticae developed on nitrogen fertilized bean plants as on unfertilized ones. Concurrently, Rodriguez and Neiswander (1949) conducted experiments with T. urticae on tomato plants and found as the electrical conductivity of the soil increased, the mite population increased significantly. Later, Rodriguez (1951) reported that increases in mite populations were associated with high concentrations of salt superfluous for normal plant growth. However, when certain ions were isolated by themselves such as nitrogen, he found negative correlations with the mite populations. Rodriguez ascertained that certain ions complement each other in stimulating mite populations. He felt that the interreaction of nitrogen and phosphorus caused an increase in mites.

In succeeding experiments Rodriguez (1958) discovered that mite populations were not totally reactive to nutrients themselves but rather the rate and amount of absorption by plant hosts. Rodriguez (1958) and Morris (1961) found that different concentrations of nitrogen, phosphorus and potassium in the plant rooting media were associated with reduced mite populations on the host plant. Morris (1961) found corresponding increases in mite populations when nitrogen and phosphorus were absorbed separately. The roles of nitrogen and phosphorus are interrelated in the plant according to Meyer and Anderson (1952). Certain nitrogen compounds are assimilated in leaf tissues when phosphorus is low which could induce mite buildup. The reverse is true when available phosphorus is abundant and nitrogen is low. This physiological concept may help in explaining mite population fluctuation in corn plants. If mites are sensitive to the rate of absorption and amount of solutes, then manipulation of these elements could alter the rate of infestations between various plants.

Plant constituents involved in the physiological process have been investigated in relation to nutrient supply and _T. urticae_. Rodriguez (1952) studied the reactions of mites to the interrelationship of minerals and the Vitamin B-complex. He found that by increasing nitrogen, he increased vitamins in the foliage of tomatoes. His results show that niacin was very significantly correlated with mite populations, thiamin and riboflavin were not significantly related, and riboflavin and niacin in combination was inconclusive. Further investigation by Henneberry and Shriver (1964) indicated that bean plants at low nitrogen levels resulted in high concentrations of amino acids in the spongy and palisade parenchynal tissue where mites were feeding. Steinberg (1951) confirms that increased amino acid concentration in mineral-deficient plants is commonplace. Henneberry and Shriver (1964) also reported that chloroplast content of the cells was low on nitrogen deficient plants which in turn reduced mite populations.

Studies by Henneberry (1962) on mite susceptibility to plant physiological changes, discovered a high positive correlation between carbohydrate content and mite levels of infestation. Phosphorus and potassium supply alone and in combination with certain levels of nitrogen to the plant in this experiment affected nitrogen absorption and total carbohydrate content of the leaf tissue. When carbohydrate was increased, with a corresponding increase in nitrogen supply and absorption, mites produced more progeny. Hamstead and Gould (1957) found that high mite populations corresponded to seasonal nitrogen peak and assimilation of carbohydrates.

Mitchell (1970) has determined that crop plants establish liable pools of carbohydrate in each leaf as it matures. When each leaf reaches 50 per cent of its final size it begins to store up photosynthate in plant tissue to later utilize for respiration or structural components. It follows then that by the time corn passes tassel all leaves have exceeded 50 per cent maturity and have begun to assimilate carbohydrates.

No mention of *Oligonychus pratensis* or *Tetranychus cinnabarinus* has been made in the previous review on the physiology of plants as related to mite development. The first plant function noted to be involved with population fluctuations of the *O. pratensis* was the apparent periods of high moisture stress and resulting wilt noted by Walter (1956) and later by DePew (1960) in wheat. Many investigators now allude to similar observations of mite infestations on crops in relation to stressed conditions during periods of drought. All three species have been observed increasing on corn under stressed conditions in the southwest area (Bell, 1971).

Drought stimulation of spider mite populations in corn have been well documented by workers (Schweissing, 1973; Ehler, 1973; Pate and Neeb, 1969; and Teetes, 1973). Rodriguez (1964) further established that drought alters plant chemistry with terminal results of increasing infestations of _T. urticae_. He further correlated drought with an increase of soluble salts which was determined to encourage high mite populations. Meyer and Anderson (1952) state that individuals of the same plant species invariably have a higher osmotic pressure when growing under drought conditions. Decrease of growth of the plant under stress permits the accumulation of mineral salts and soluble foods, and a shift of the starch-soluble carbohydrate equilibrium towards the soluble carbohydrate phase. The influence of water stress causing salt buildup was also depicted by Kramer (1969). He indicated that drought brings cessation of growth causing salt contents of cell vacuoles to increase. Work by Slayter (1969) establishes carbohydrate buildup in leaves in periods of water deficits. He found it probable that the translocation system became less efficient and assimilates were accumulated at the sites of photosynthesis.

The proposed theories of spider mite increases (all three species) in reaction to salt and carbohydrate accumulation in plants under water stress presents an interesting correlation with observations by researchers on corn. Corn, even with abundant irrigation, undergoes severe degrees of moisture stress during the months of hot dry winds because of the roots' inability to absorb water at the rate it is lost to the atmosphere. These periods of high temperature and desiccating winds compare with periods of high mite infestations in Southwest Kansas (Bell, 1974).

In reviewing the various observations on the related physiological effects of plants on spider mite populations, it appears that plant nutrients are involved as a mechanism triggering mite infestations. The indirect effect of nutrient involvement, especially nitrogen, in the formation of carbohydrates and the accompanying assimilation during periods of water stress on the plant presents an interesting possibility of mite population regulation. Accumulation of salts during physiological drought and the relation of leaf age to carbohydrate content and corresponding mite populations, further stimulate a high degree of interest for understanding the relationship between plant physiology and mite populations. Much additional experimentation is needed before it will be possible to define more precisely the significance of altering the condition of the host plant and the resulting effect on spider mite control.

Agronomic Effects in Relation to Mite Populations

Various agronomic problems have been observed in corn after heavy infestations of spider mites. These problems often are entwined with other parameters of corn production and make isolation of mite damage difficult. Accompanying reductions in total plant potential include stalk breakage, reduced ear size, ear fill and light test weight (Schweissing, 1964; Pate and Neeb, 1969; Bacon et al., 1962).

Since it has been established that the heaviest concentrations are normally encountered under water stress conditions it would be difficult to ascertain whether the problems observed are from mite infestations, stress conditions or a combination of both. If the assumption is made that moisture stress intensified mite population then it would follow that infestations would magnify moisture deficiencies. Moisture stress during periods of tassel, floral initiation and grain development can seriously reduce yields from 22 to 50 per cent (Slatyer, 1969). If severe spider mite feeding can induce symptoms of water stress in corn then observed problems of reduced ear size, ear fill and light test weight of grain could result. Unfortunately, variables due to plant structure and environment exist that are tremendously difficult for investigators to isolate.

Workers attempting to ascertain chemical controls on mites have reported increased stalk breakage on infested plots. Bacon et al. (1962) found that in his corn plots with no chemical treatment to control mites, the number of broken stalks and plants infected by stalk rot were significantly higher than the treated plants. Later in working with irrigated corn in Colorado, Schweissing (1964) reported significant increase in lodging on his untreated plots as compared to treated. Pate and Neeb (1969) observed lodging in heavily infested fields of sorghum in Texas. They suggested that the mite may have indirectly affected lodging by indirectly making the plant more susceptible to charcoal rot and other stalk rotting organisms by placing it in a stressed condition. Conflicting results were reported by Cate and Bottrell (1969) in the same year on sorghum. They observed no lodging in their experiment with O. pratensis on grain sorghum. Nor were they able to determine any significant reduction in test weight or yield.

However, it should be noted here that the mite infestations were induced only for a short period of time on their investigations before spray applications were made. Ward et al. (1972) performed extensive experiments with chemical treatments for mite control on corn and sorghum. The investigators reported extreme variations in number of plants lodged or fallen when they compared the effectiveness of control chemicals. Plots receiving inadequate control had a greater amount of stalk breakage and charcoal rot infestations. Additionally, plants were observed to be kept from growing to normal size because of excessive mite feeding.

Observations by investigators appear to have determined a certain amount of stalk breakage and related pathological infestations due to mite feeding. The extent of pathogen influence as related to lodging was not defined. Whether mites reduce stalk strength independently or are the mode of infestation for disease producing organisms can only be determined by further investigation of this related agronomic problem.

Control Measures Influencing the Population Dynamics of Spider Mites

The parameters which influence the population dynamics of spider mites are interrelated to the extent that evaluations of the physiological effect of the host plant can not be considered without taking into account the natural and chemical control measures that may be involved. Natural control measures involve the association of weather, physiological maturity, plant variations and predators. These conditions in turn may produce a profound effect on chemical control procedures when evaluating pesticide types, application schedules and resistant biotypes.

Natural Controls and the Related Physiology of Host Plant. Weather continues to be one of the single most important influences on spider mite infestations reported. Low winter temperature was found by van de Vrie et al. (1972) to cause heavy mortality in overwintering females of the Tetranychus urticae. Temperature seemed to have a role in inception and/or termination of diapause stage. High temperatures during the month of February was reported by these workers to increase survival on this particular species. Further limitations imposed by temperature on the twospotted spider mite were noted by Cagle (1949). He noted that incubation period of eggs fluctuated between 2.5 days at 30 to 34 C. and 19 to 20.5 days at 12 to 15 C. On the same species Oatman and McMurtry (1966) found abrupt increases in populations in the field when a cool, rainy period was followed by rapidly rising temperatures and no rainfall.

Similar temperature effects have been reported on Oligonychus pratensis by Malcomb (1954) who first reported that as temperatures increased toward 70 F. the length of the immature stage of mites was shortened. Field observations by Hantsbarger (1972) and Schweissing (1973) in Colorado indicated similar findings. Texas researchers found hot dry weather to enhance the mites ability to multiply very rapidly on corn and sorghum (Ward et al., 1972). Spider mites on corn favored hot weather for development of populations and cool weather seemed to hold the mite populations at a standstill.

Humidity is also an important factor in spider mite production on the corn plant. The effect of humidity on mites seems to revolve around increased egg production, greater longevity of females and increased feeding rates. Boudreaux (1957) in his study of the effect of humidity on Tetranychus urticae and Tetranychus cinnabarinus discovered a faster ovipositing rate and a greater number of eggs laid by females in a dry atmosphere. He found no effect on the hatching of eggs but he did detect a low survival rate for young under moist atmospheres as compared to dry. Increased feeding activities of mites under low humidity was also cited. The results were explained on the basis of the need to ingest larger amounts of food and water in a dry atmosphere because of body moisture loss by evaporation from the cuticle. He further suggested that water loss by evaporation from the cuticle is necessary for the most favorable utilization of the liquid cell contents ingested by mites. Wharton (1963) suggested the feeding of mites and resulting injury was related to the water imbalance brought on by high temperatures and low humidity.

Nickel (1960) found higher egg production when the humidity was lowered to 25 to 30 per cent in the surrounding environment. Rodriguez (1954) has also shown an increase in egg longevity. His experiments were conducted within the confines of petri dishes and he made no assumption on feeding rates.

Earlier references were made in regard to movement of the spider mite in relation to environmental changes. Hussey and Parr (1963), working with T. urticae, found that when humidity was reduced to 30 per cent there was a corresponding increase of mite migration compared to 80 per cent humidity.

The effects of wind on dissemination have been discussed earlier in the text. It was generally agreed that wind was the primary disseminator of the three species of spider mites (Fleschner et al., 1956; Boyle, 1957). Wind adds an additional dimension to the combined effects of temperatures and humidity. Under conditions of high temperatures and low humidity, wind would further increase cuticle evaporation from the mite and/or increase the amount of desiccation of the plant, indigenous to mite feeding.

Rainfall is another weather condition that is involved in considerations of mite potential. It closely ties in with the effects of humidity and temperatures. The impact and washing force also appears to have a detrimental effect on mite infestations. Heavy rain in Western Kansas was noted to reduce spider mite infestation during the summer of 1974 (Bell, 1974). Boudreaux (1957) referred to the beating action of rain which washed off active stages of the T. urticae complex from plant leaves. Heavy rains on sorghum fields under chemical control studies destroyed populations of O. pratensis for periods of 14 days after rainfall was received (Teetes, 1973). Schweissing (1968) reported a substantial reduction of Banks grass mite in corn in Eastern Colorado following severe rainstorms.

The total effects of light on mite populations have attracted little attention from researchers. Hussey and Parr (1963) worked with light as a factor in migrations. They observed T. urticae in direct sunlight and found no increased dispersal. Spider mites were noted to be very active but produced no notable migration to less infested leaves. Daily rhythm of oviposition in response to sunlight was studied by Polcik et al. (1965). His workers found oviposition frequency in *T. urticae* dropped shortly after experimental nightfall and increased to normal levels after sunrise.

Physiological maturity of leaves was discussed to a limited extent in relation to leaf age and assimilation of carbohydrates. Using three maturity ranges on corn, short, medium and long, and three planting dates, Schweissing (1969) has shown that early maturing varieties and early planting dates were associated with highest mite populations and damage. The longest maturing variety planted on May 10 appeared to produce the best yield results.

Field observation by Pate and Neeb (1969) on sorghum indicates there were variations in mite populations according to the stage of maturity of the sorghum. Extremely high infestations were observed in grain at milk stage and normally did not desiccate sorghum until after soft dough stage. Greenhouse studies on corn in Kansas revealed a significant difference in number of eggs laid and survival rate of *Oligonychus pratensis* on mature silking corn than on seeding corn (H. D. Freese, unpublished data, 1973. Preparation for Ph.D. Thesis, Kansas State University, Manhattan, Kansas).

Host plant resistance among varieties offers the best opportunity for a total control program for mites. If plant resistance can be isolated and developed even at a partial or modified level, the impact of cultural controls, chemicals, weather and predators would be multiplied. Unfortunately very little work has been performed to select resistant host plants to the Banks grass mite, twospotted spider mite and carmine spider mite. Schweissing (1973) began the initial work of selecting resistant corn varieties. He screened 993 cultivars in 1972 for resistance to the Banks grass mite. Of these, 20 were selected for resistance and are undergoing further screening in the field and the greenhouse.

Work on the twospotted mite complex with host plants has been limited to vegetable studies. General observations and some detailed records reveal that different plant species or varieties present different potentials for tetranychids (van de Vrie et al., 1972). Tomato varieties were reported to have different levels of tolerance to _T. urticae_. Resistance was associated with the reduction in fecundity of _T. urticae_. The oviposition rate was determined to be affected on _T. cinnabarinus_ when examining varietal resistance in tomatoes. Upon close examination, the variations between plants were associated to an extent with the number of grandular hairs on the leaves.

Biological Control of the Spider Mites. Predators of the three species of mites known to infest corn in Southwest Kansas offer the growers one more means of natural control. Natural enemies of the Banks grass mite, twospotted spider mite and carmine spider mite have been the subject of considerable examination. Most of the investigations have centered around the insect orders of Thysanoptera, Coleoptera and the predacious mites of the class Acarina. The potential of these predators as a means of biological control is limited by the same parameters which affect population levels of the spider mite. Weather, host plants and chemicals influence the ability of predacious insects to control expanding spider mite populations during active periods.

Malcomb (1954) in his original work identified several insects feeding on Oligonychus pratensis. Two species of coccinellids, Hippodamia convergens, the convergent lady beetle, and Coccinella transversoguttata, transverse lady beetle, were found in substantial numbers feeding on mites. Stethorus picipes along with two species of predacious mites, Typhlodromus fallacis and Typhlodromus cucumeris, were included among the species frequently found feeding on Banks grass mite. No reaction of predators to effects of environment was noted. In New Mexico, Harvey (1954) observed predatory thrips, Scolothrips sexmaculatus, feeding on O. pratensis. He found that mite populations were significantly higher in plots treated with dieldrin due to the action of the chemical reducing thrip populations. A survey study was conducted by Dean (1957) in Texas on corn and sorghum to determine predators of O. pratensis. The study disclosed nine predators: Stethorus punctum, Scolothrips sexmaculatus, Orius insidiosus, Hippodamia convergens, Chrysopa rufilibris, Olla abdominalis, Typhlodromus fallacis, Pronematus ubiquilus and Typlodromus mesembrinus. Of the nine insects Scolothrips punctus ? and S. sexmaculatus were found to be the most effective predators feeding on dense mite populations. The dominant predacious mite species determined to be preying on O. pratensis in Southwest Kansas was Neoseiulus fallacis (Garmen) (Bell, 1972). Included in the observation were the predators Orius insidiosus, a cecidomyiid fly, and a Scolothrips species attacking the spider mite populations.

Various workers have reported effective control of Tetranychus urticae with a predacious mite, Phytoseiulus persimilis in vegetable and fruit crops (Chant, 1961; Oatman and McMurtry, 1966; and Markkula and Tiittanen, 1972). They considered chemical versus predator control and determined the use of P. persimilis as being more economical. A thrip, Scolothrip sexmaculatus was noted by Oatman and McMurtry (1966) to be a more common predator than the P. persimilis. They determined that the number of mites per leaf was a better criteria for timing the release of predators than per cent of leaves infested. P. persimilis was investigated by Pruszynski and Cone (1972) in relation to its predacious effect on twospotted spider mites. These workers found that P. persimilis have effective predators of its own eggs and larvae, and was not effective as a control. Instead they found a species, Typhlodromus occidentalis, to be a better candidate for control on hops.

Several species of the predaceous mite genus, Typhlodromus, were observed to be feeding on T. urticae in laboratory tests (Herbert, 1959). Mites feeding on various development stages included: Typhlodromus tiliae, T. rhenanus, T. finlandicus, Phytoseius macropilis, T. fallacious and T. corticis. Studies on integrating predator controls with cultural practices, chemical applications and release of P. persimilis were initiated by Oatman et al. (1967). The dominant predator that emerged in the experiment was again the thrip,

S. sexmaculatus, which accomplished the greater amount of control. P. persimilis did destroy an average of 18.9 per cent of the T. urticae populations. Spider mite populations increased substantially after chemical application in this experiment.

When comparisons of predators are made between the literature reported on the Banks grass mite and the twospotted spider mite, it is evident that the predator common to both is the thrip, S. sexmaculatus. Other predators may be common to both but have not been reported in the literature. Of importance when discussing the potential of these predators, is their susceptibility to biological and meterological influences. Herbert (1956, 1962) found that Typhlodromus titial, a predacious mite on T. urticae, increased in number and feeding habits as temperatures increased. Prey synchronization was found to be the dominant control factor by Huffaker et al. (1963). Without an increase in prey to correspond to predator mite increases, predator populations begin to decline which allowed a resurgence of prey and resulting plant damage. Introduction of new species into areas in order to control existing populations have met with little success according to Huffaker et al. (1970). The condition of the host plant remains a dominant factor affecting the success and abundance of spider mites. Weather, season growth cycle, water, soil nutrients and pesticides further affect the impact of the induced predator.

Chemical Control Relationships to Plant Physiology and Mite Populations. Chemical controls open up an entirely different approach to spider mite control in corn. Chemical treatments add a new relationship to the plant-mite complex. It has been well documented that ground and foliar chemical applications disrupt both the physiology of the plant and the biology of spider mites to include the predators (van de Vrie et al., 1972). The extent of the disruption and what further complications are caused by chemical applications is yet to be determined.

According to van de Vrie et al. (1972) applications of agricultural chemicals to the foliage may conceivably affect certain of the described complex relationships or act in other ways to alter the plants attractiveness to spider mites. Among the first to detect increases of population densities of Tetranychus urticae associated with treatment with DDT was Huffaker and Spitzer (1950). They ruled out elimination of predators as the cause and suggested physiological stimulation due to nutritional and hormonal nature of the plant. Klostermeyer and Rasmussen (1953) expanded their finding in their work with DDT, benzene hexachloride, lindane, aldrin and chlordane in the soil. They noted increases in spider mite populations on bean plants which were attributed to the changes in plant composition induced by insecticides in the soil. More detailed experimentation by Rodriguez et al. (1957) with six different insecticides, three species of plants, and three variations of macronutrients found that population densities varied with combinations. The investigations detected different degrees of mite infestations depending on the stimulation effect of soil insecticides on plants and the assimilation of nitrogen, phosphorus and potassium. Significant correlations between mite levels and plant nutrients were determined.

Rodriguez, Chan and Smith (1960) and Rodriguez, Maynard and Smith (1960) determined that by adding DDT to bean, cotton and soybeans, the reducing sugar and nitrogen (and T. urticae populations) were increased. In addition, they found that phosphorus and potassium in the plant were reduced. Other chemicals: benzene hexachloride, lindane, dieldrin, aldrin and chlordane were shown to also cause an increase in the reducing sugar glucose. The results of their experiments demonstrate that at least one organic constituent of the plant, reducing sugar, is influenced in the plant by addition of certain insecticides.

Results of Saini and Cutkamp (1966) varied somewhat from other researchers. They detected no significant differences on T. urticae populations when exposed to various levels of DDT. Mite populations did increase, however, when increased sucrose and nitrogen were supplied. No response was detected to increased glucose by the researchers.

Henneberry (1964) further supported the effect of host plant relationships to T. urticae populations when chemicals were applied. He found a greater increase in the fecundity of spider mites as a result of a foliar application of malathion to the host plant. In the review of van de Vrie et al. (1972), foliar application of parathion and carbaryl were determined by investigators to increase reproduction of T. urticae. In the case of parathion, the phosphorus content was increased in the leaves of peach causing increased mite production. Carbaryl, on the other hand, was demonstrated to have a marked influence on the potassium:calcium ratio. Applications of carbaryl early in the season reduced the ratio which caused an increase in amino acids and reducing sugar, triggering increased egg production of T. urticae and T. cinnabarinus.

Investigations are not available on pesticide effects on host plants and related mite population changes of the O. pratensis. Nor is there any specific research on any of the three species of mites on corn.

Certain studies have disregarded the effect of the chemical on the host plant and attributed the increase in spider mite populations to the biology of the mites and/or a decrease of predators. Schweissing (1973) observed in his field studies on corn that predators of the O. pratensis were destroyed after application of parathion or carbaryl and severe damage by mites followed. Dittrich, Streibert and Bathe (1974) discovered that spray residues of carbaryl, DDT and dioxacarb produced a shift in the F_1 generation of T. urticae to a higher ratio of females which in turn produced a significantly higher number of eggs. Carbaryl demonstrated the most pronounced effects of the chemicals tested. The researchers postulated that hormoligosis, the stimulation by small quantities of a stressor, was responsible for increased mite infestations. They did not believe the increase was due to improved nutritional basis because of altered physiology of the host plant. Earlier work by Attiah and Boudreaux (1964a, 1964b) revealed that DDT indirectly caused greater dispersal of T. urticae by removal of natural enemies. When mites moved to predator-free surfaces and established new colonies, an increase in population to economically harmful levels resulted. In a separate experiment they could find no evidence that F_1 generations produced any greater numbers due to stimulation effect of DDT. Cone (1963) observed similar results when working with DDT and carbaryl on alfalfa. The twospotted spider mite showed no increase in fecundity.

Barlett (1968), in his experiments with 59 different pesticides, reported no conclusions on _T. urticae_ increases due to either natural enemy destruction or pest fecundity stimulation. He recognized the existence of several upsets in populations from chemicals and attributed these to toxic effects on predators. Many of the upsets also corresponded to seasonal patterns of natural enemy activity. He further recognized that certain pesticides do stimulate the reproduction rate but could find no evidence as to how the action occurred. McMurtry, Huffaker and van de Vrie (1970), in their review on the impact of chemicals on predators, postulated that insecticides are more hazardous to some enemies of spider mites than to others. The indirect influence of agricultural chemicals was less obvious, but may well be equally detrimental to effective predator action, according to the investigators.

Effectiveness of chemical controls.-Chemicals effective against spider mites on corn and sorghum have drawn the attention of many investigators in recent years. The potential threat to corn alone has stimulated the testing of a large assortment of products and to evaluate each one on a merit basis is beyond the scope of this discussion. The purpose of ensuing discussions will not be to consider the effectiveness of each product but to determine the total effect of spray programs on yield and time of application.

The total impact of a spray program is difficult to assess without comparable yield data, stage of maturity, chemical applied and injury ratings. This type of information is a necessity for determining a point at which a chemical can be applied at the right maturity stage and infestation level to attain maximum economic benefits. Several workers on corn and sorghum have obtained results with tests but the total value is difficult to assess without yield data (Teetes, 1973; Pate and Neeb, 1969). No difference between control plots and chemical treatment may have caused these researchers to refrain from collecting yield data.

Earlier work by Bacon et al. (1962) on dent corn in California produced significant differences in yields between treated and untreated plots. Ethion treated plots produced larger ears with plump well-filled kernels and a higher test weight. Ears from checks were shriveled and "loose." The yield was greatly affected by the stage at which corn underwent heaviest infestations. Heavy feeding at silking time or during milk or early dough produced the most severe shriveling in ears. The extensive four year study of acarcides on corn and sorghum by Ward et al. (1972) returned positive results on chemical applications during 1970. Yield increases were observed in corn plots with aerial applied chemicals. The 1967 and 1968 tests indicated chemicals to be effective in reducing O. pratensis; however, no differences in yields were noted. The 1969 tests showed favorable results on yields and in controlling Banks grass mite. It should be noted that the tests were conducted at different locations in 1967 and 1968 as compared to 1969 and 1970. Klostermeyer (1961) in his experiments with dent corn in Washington found no increase in yields when mite populations were chemically controlled. Mite population counts were taken at weekly intervals in this experiment conducted for a two year period. Counts made on the damaging levels of O. pratensis differed between the experiments previously reviewed making comparisons difficult.

Chemical application timed to coincide with the best agronomic benefits has been ignored by most investigators. The magnitude of variables which may enter into experiments attempting to determine best maturity stages and/or infestation levels to apply pesticides may well explain the lack of work in this area. After a series of experiments with O. pratensis on corn in Eastern Colorado, Schweissing (1973) determined through field observations a point at which chemical application is needed. He indicated chemicals should be applied when mites are infesting the lower third of the leaves. Emphasis was placed on insuring that the populations were forming webbing on all the bottom third of the leaves with continuous infestation, to the extent that yellowed areas were showing through the upper surface of the leaf. Hagen (1973) in his field observations in Nebraska noted that controls should be applied to corn before infestations reached the ear level which would include the bottom third or bottom half depending on ear location. He gave no indications as to the extent of infestations per leaf that may be allowed.

Development of resistant strains of spider mites.-One of the major concerns of many workers is the evolution of resistant strains of the O. pratensis, T. urticae and T. cinnabarinus in corn. Investigators are already establishing that resistant strains to certain chemicals have developed. Helle (1965) revealed that a single major gene accounts for the resistance of T. urticae strains to parathion. He found resistance was dominant and transmitted by both sexes. Similar results in malathion resistance were obtained by Smith and Taylor (1956) in their experiments with the twospotted spider mite complex. Crosses of resistant females and nonresistant males produced all resistant offspring. Haploid males were found to have the same resistance as the maternal parent. Smith and Fulton (1951) when surveying resistant spider mites found two strains that were resistant to parathion and carried this resistance to other organic phosphates. On further experimentation they found resistance was not lost when mites were not exposed to chemicals for long periods. No morphological differences could be found between their resistant and nonresistant spider mites.

Resistant strains have been found to develop locally by outcrossing with mites in adjacent area. McEnroe (1970) found that local _T. urticae_ had the potential to establish resistance by outcrossing with adjacent resistant strains. When resistant outcrossing occurred mites showed more genetic variability, presumably due to frequency of outbreeding. Movement by females away from heavily populated areas assisted in providing opportunities for outcrossing with resistant varieties (Mitchell, 1973). Boudreaux (1956) in his discussions on the twospotted spider mite outlines the ability of the complex to hybridize. The offspring of _T. cinnabarinus_ and _T. urticae_ did not produce viable young but lived twice as long, offering another dimension for development of resistant strains.

Resistance to various acaricides has been noted to be developing in _O. pratensis_ (Ward et al., 1972). Results of experiments with several acaricides on corn and sorghum in Texas indicated that heavier applications were needed to control the mite as resistance increased.

Under modern agricultural methods, possibilities for resistant mite outbreaks increase each year. Growers tend to use stronger chemicals applied at a diluted rate to gain speed in application. The problem of increased resistance may be solved temporarily by using chemicals for which no resistance has yet developed. However, if improper application methods are employed, the potential of resistance emerging against even the strongest treatment is not unreal. Knowledge of integrated control methods to include intelligent use of specified chemicals still prevails as the best protective measure.

AGRONOMIC FIELD OBSERVATIONS ON SPIDER MITE DEVELOPMENT IN SOUTHWEST KANSAS

Methods Used for Field Observations

Growers in Haskell County, located in Southwestern Kansas, encountered economically damaging spider mite infestations in corn fields during 1970-1974. The area appears to be infested with increasing population levels each year. In the spring of 1974 the decision was made to include a larger acreage of dent corn in the already existing Pest Management Program in Haskell County. The program had begun operating in 1973 predominantly on grain sorghum acreage in Haskell, Meade and Stevens Counties. The large influx of corn acres, 97,920 as compared to the 21,600 acres of grain sorghum, made it necessary to initiate an extensive pest management program in corn. Growers were in need of a field inspection process at regular intervals to determine the extent of insect infestations and the necessary control actions to prevent damage.

The pest management program was extended to 5,477 acres of dent corn in Haskell County in 1974 under the guidance and support of USDA, Kansas State University Extension Service and the Haskell County Extension Council. Field scouts were utilized to provide regular inspection of corn fields and report infestation levels of spider mites as well as other insects invading corn fields. The program assisted growers in determining damaging levels of insect attack and needed pest management techniques utilizing natural controls, proper chemical application and accurate insect identification.

In order to provide uniform field inspections, a system of reporting spider mite damage was devised which would provide needed reports to advise growers on control measures and simultaneously gather field information for evaluation as to the impact of spider mite damage. Fields were inspected at weekly intervals for mite infestations by examining 5 plants at two different locations in the field and recording number of live, infested, injured and dead leaves on the corn plant. Averages were determined and transferred to weekly reports on each field. Infested leaves were based on the presence of mite populations without regard for injury. Injured leaves consisted of any discoloration due to mite feeding and dead leaves were determined in regard to their inability to function as an entity of the plant.

Areas of infestation per field were included by scouts on weekly observation sheets. A simple rating was utilized consisting of: 0 for no infestations; 1 for infestations localized in small areas; 2 for infestations limited to one or more general areas; and 3 was for infestations present throughout the corn field. The concept of identifying areas of infestations was included in observations on each plant sampled. Ratings of 0 meant no infestations on plant; 1 indicated infestations were limited to the bottom one-third of the leaves; 2 signified populations were present in the top two-thirds of the plant and 3 ratings revealed infestations to be occupying the leaves in the top one-third of the plant as well as the lower two-thirds.

Growth stages were observed during each inspection on the field involved in the pest management program. Maturity ranges of the corn plant were divided into a total of 10 stages in order to monitor the advancement of the spider mite infestations in relation to physiological plant development. The growth stages included:

0 - from emergence to 3 leaves
1 - 4 to 7 leaves fully expanded
2 - 8 to 11 leaves fully expanded, normally knee high
3 - 12 leaves fully emerged, normally waist high
4 - tip of tassel showing
5 - first silk showing
6 - blister stage of the ear
7 - dough stage
8 - ears are showing dent
9 - full dent with kernel hardening

The coding method employed by scouts to record the growth stage of the corn was designed by Hanway (1971). Additional limitations were applied to the various maturity ranges when the field observations required a more defined explanation.

Samples were taken during the summer growing season to determine the species of spider mites present. The identification reports of spider mites in 1973 ran approximately 50 per cent Oligonychus pratensis, Banks grass mite and 50 per cent Tetranychus urticae, twospotted spider mite (J. D. Stone, personal communication, 1974. Research Entomologist, Garden City Experiment Station, Garden City, Kansas). No samples of

Tetranychus cinnabarinus were identified in the 1973 field observations in Haskell county. Both the twospotted and the Banks grass mite samples were identified from the same field on a number of the reports. Samples taken in 1974 resulted in only the *O. pratensis* being identified.

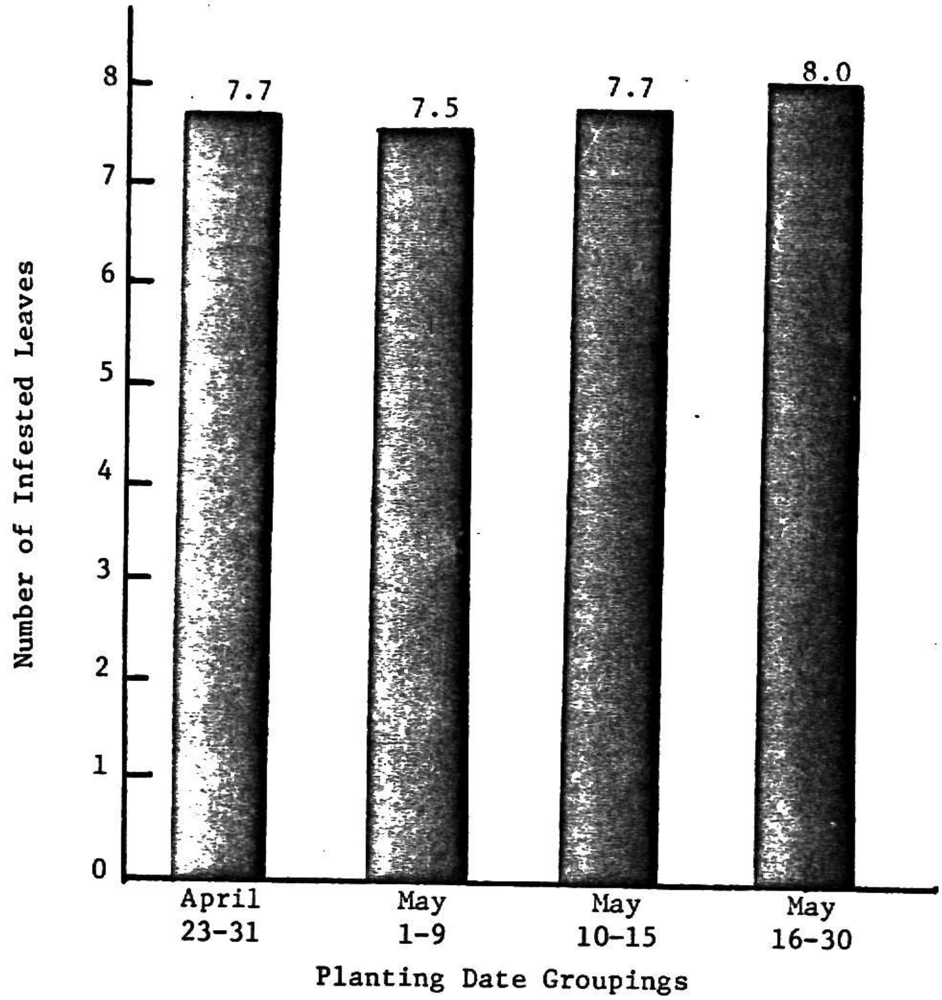
Results

Planting dates in relation to degrees of mite infestation were compared among 47 fields under observation in Haskell County. Mite infested and mite injured leaves were counted at regular intervals throughout the summer growing season. All varieties were of the medium to late maturity range (120-130 days). Field observation comparisons were made as the corn reached the soft dough stage (stage 7). This particular stage normally corresponded to the highest levels of infestations during the season. Planting dates were partitioned into four groups in an attempt to determine differences between two early planting periods and two late planting periods. The planting periods were identical to the planting date groupings utilized by growers in the area.

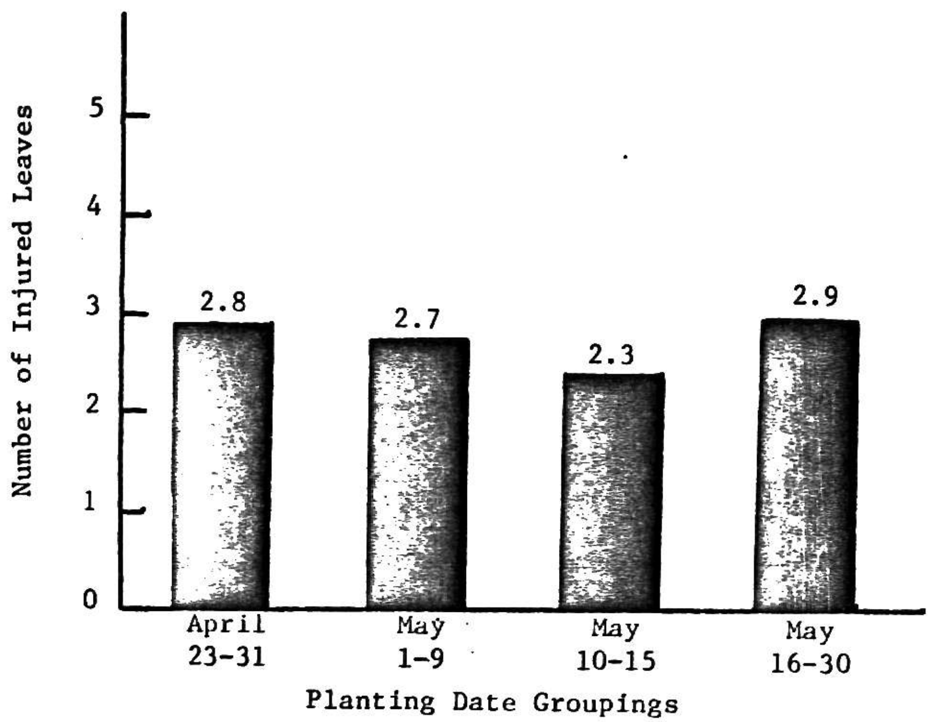
Using the Pearson method with one degree of freedom, analysis was made between planting dates and highest levels of infestations, but no correlation could be found. Figures 1 and 2 represent the planting date groupings with the number of injured leaves and infested leaves. No significant differences were observed from this comparison. The later planting date of May 16-30 tends to show a heavier injury rate and infestation level. Lack of uniformity of management between the

FIGURE 1. Infested leaves per plant and plant date groupings for 47 corn fields under observation in Haskell County, Kansas.

FIGURE 2. Injured leaves per plant and plant date groupings for 47 corn fields under observation in Haskell County, Kansas.



Number of Infested Leaves
8
7
6
5
4
3
2
1
0
7.7
7.5
7.7
8.0
April 23-31
May 1-9
May 10-15
May 16-30
Planting Date Groupings



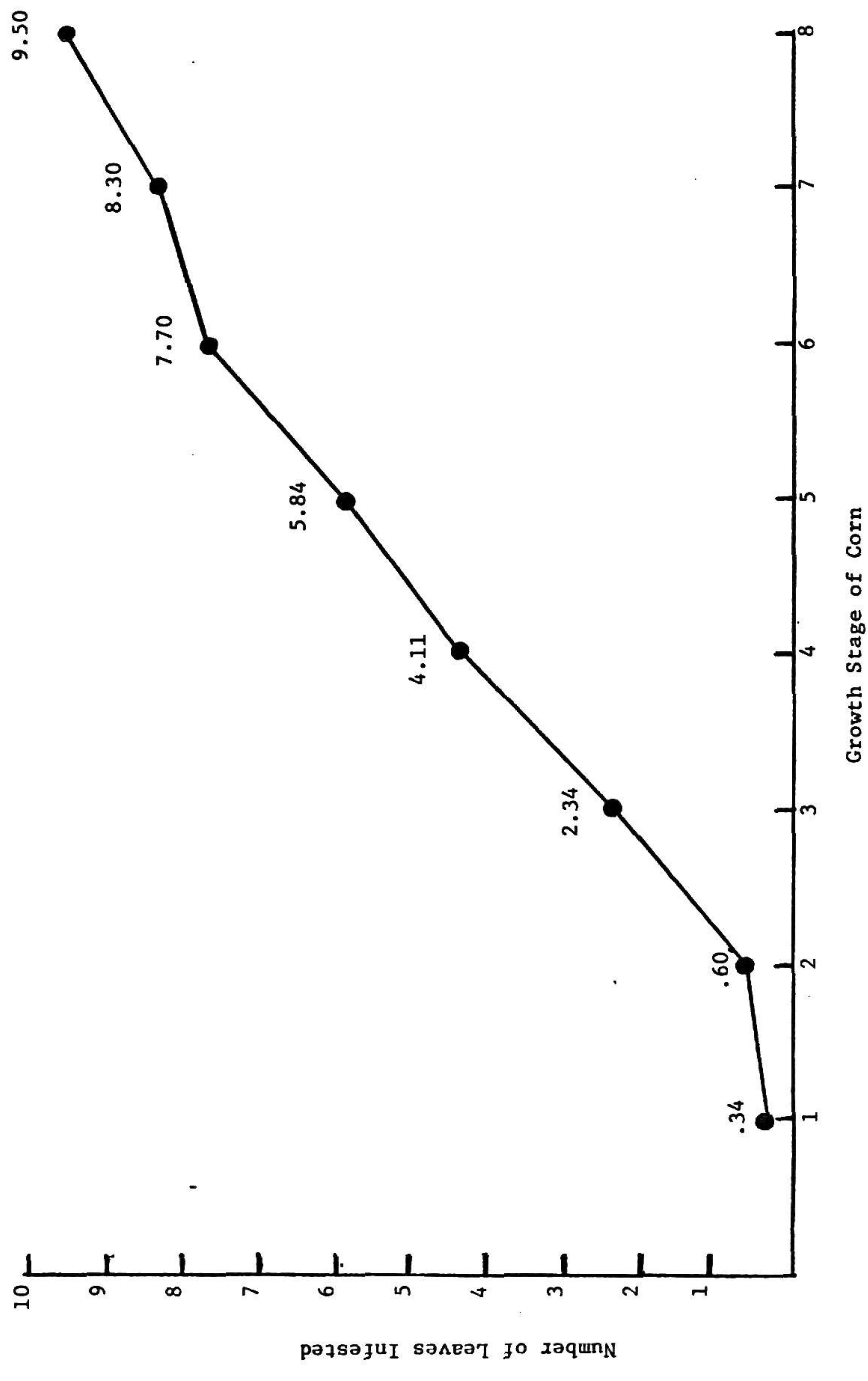
Number of Injured Leaves
5
4
3
2
1
0
2.8
2.7
2.3
2.9
April 23-31
May 1-9
May 10-15
May 16-30
Planting Date Groupings

47 fields could explain the absence of correlation between degrees of infestations and planting dates in the field observations. Differences between irrigation schedules, spray applications and maturity rates of varieties would suffice to further reduce the effectiveness of the results.

Growth stages of the corn compared to infestation levels produced the most significant correlations in the program. Figure 3 depicts the growth stage of corn as it relates to the average number of infested leaves at the highest level of infestation per growth stage. Correlations ran on the comparison show a high degree of significance with a continuous increase in the infested leaves as the corn progressed to physiological maturity. A coefficient of .7839 was established for the 55 fields. The most extensive increase of infested leaves took place from tassel through blister stage in the fields. No information was gathered after corn began 50 per cent dent. This prevented the determination of a point in which the curve would level off as populations receded. The almost linear appearance of the comparison gives rise to the question whether the observation was a result of the maturity stage of the corn or strictly a direct increase in population in relation to time.

Further examination of the field observation reports indicate a high degree of correlation with the growth stage and the number of injured leaves per plant. Analysis established a correlation coefficient of .5117 with 55 fields examined. The relationship produced an almost linear progression from stage 2 with 6 to 8 leaves

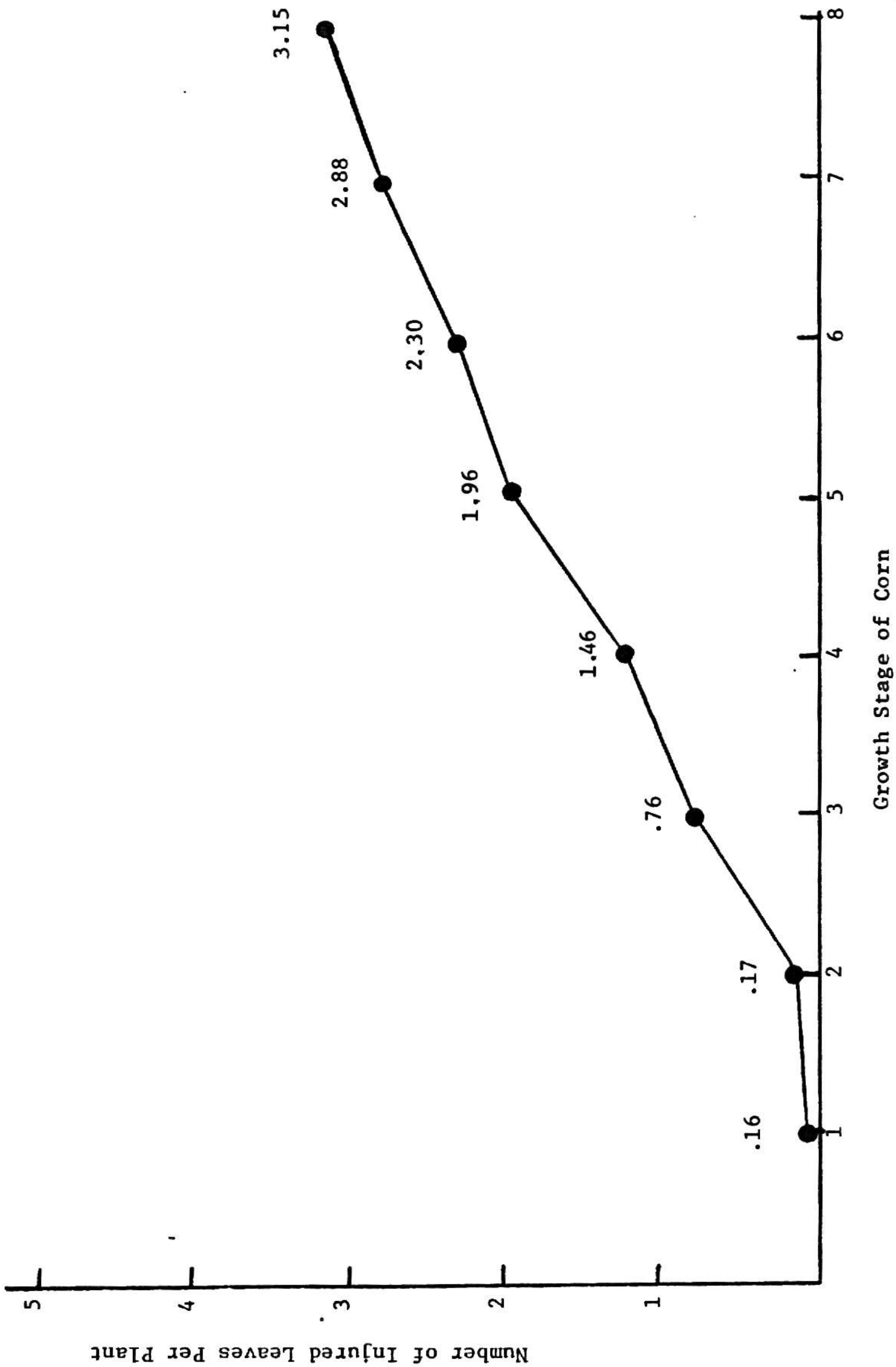
FIGURE 3. Growth stages of corn and the average number of infested leaves per plant at the highest level of infestation.


Number of Leaves Infested
Growth Stage of Corn
1
2
3
4
5
6
7
8
9
10
.34
.60
2.34
4.11
5.84
7.70
8.30
9.50

fully expanded up to and including stage 8 with corn at 50 per cent dent (Figure 4). Again lack of information prevented finding a point at which injury levels diminished. The injury levels consistently lagged behind the infested leaves which was to be expected. Chemical application to the fields was accomplished between stages 5 and 6 for the majority of the corn. No significant reduction in the level of infestations between stages could be observed. It should be noted that the injury levels would continue to be reported despite spider mite kill by aerial application, thus no severe drop in damage would be observed. However, infestation ratings continued to build without regard for spray practice, instead of holding at the last reported injury level prior to application, which would have indicated effective chemical action. The maximum number of injured leaves per plant attained in the dent stage was 3.1 over all fields surveyed. This was compared against a total average live leaves per plant of 13.7 in the 47 fields considered for mite infestation and injury.

The advancement of infestations upward in the corn plant provided another significant degree of correlation with the growth stage. Infestation areas of the bottom third (4 leaves), middle third (5 leaves) and the top third (4 leaves) were compared with growth stages. Populations needed only to be observed establishing in each of the three sections, and were not evaluated on total extent of infestation per leaf, before they were reported infesting any particular area of the corn plant. Thus, infested areas were averaged to gain an insight as to what degree of advancement the 47 fields were in per growth stage.

FIGURE 4. Growth stages of corn and the average number of injured leaves at the highest level of infestation in Haskell County, Kansas.


Number of Injured Leaves Per Plant
Growth Stage of Corn
1
2
3
4
5
6
7
8
.16
.17
.76
1.46
1.96
2.30
2.88
3.15

The normal progression of the spider mites was to infest the lowest leaves; then as feeding areas diminished and populations increased, movement would be to the next highest leaf. Complete dispersal was noted in certain fields before populations would build up on lower leaves. Scattered colonies were noted over the entire plant in these cases with no particular heavy degree of infestation on the lower leaves first. No attempt was made to separate the infestation progression upwards from the scattered infestations throughout the plant.

Figure 5 shows the progression of infestations up the plant as various growth stages are reached. Very little movement of infestations were noted from corn emergence to early tassel on 55 fields. Populations remained below the bottom one-third of the plant in the lower leaves. As the first silk stage of the corn was approached, mite populations began building past the bottom third and progressed upwards through growth stages 5, 6 and 7. On all fields observed in dent stage, populations had moved up into the top one-third of the plant. Fewer observations were made at this stage which could account for the frequency of plant area 3. Spider mite movement was determined to be the most pronounced during stages 5, 6 and 7 which corresponds to the high degree of infested and injured leaves reported in the same stages of maturity in Figures 4 and 5.

Spray dates as compared to growth stage and the before versus after comparisons of infested leaves, injured leaves and infestation areas were compiled in Table 3. The chemicals were applied aerially to all fields at the rate of 1.2 - 1.5 pounds of ingredient in 3-4

FIGURE 5. Growth stages of corn and areas of infestation on the plant taken at highest degree of spread on the corn plant.

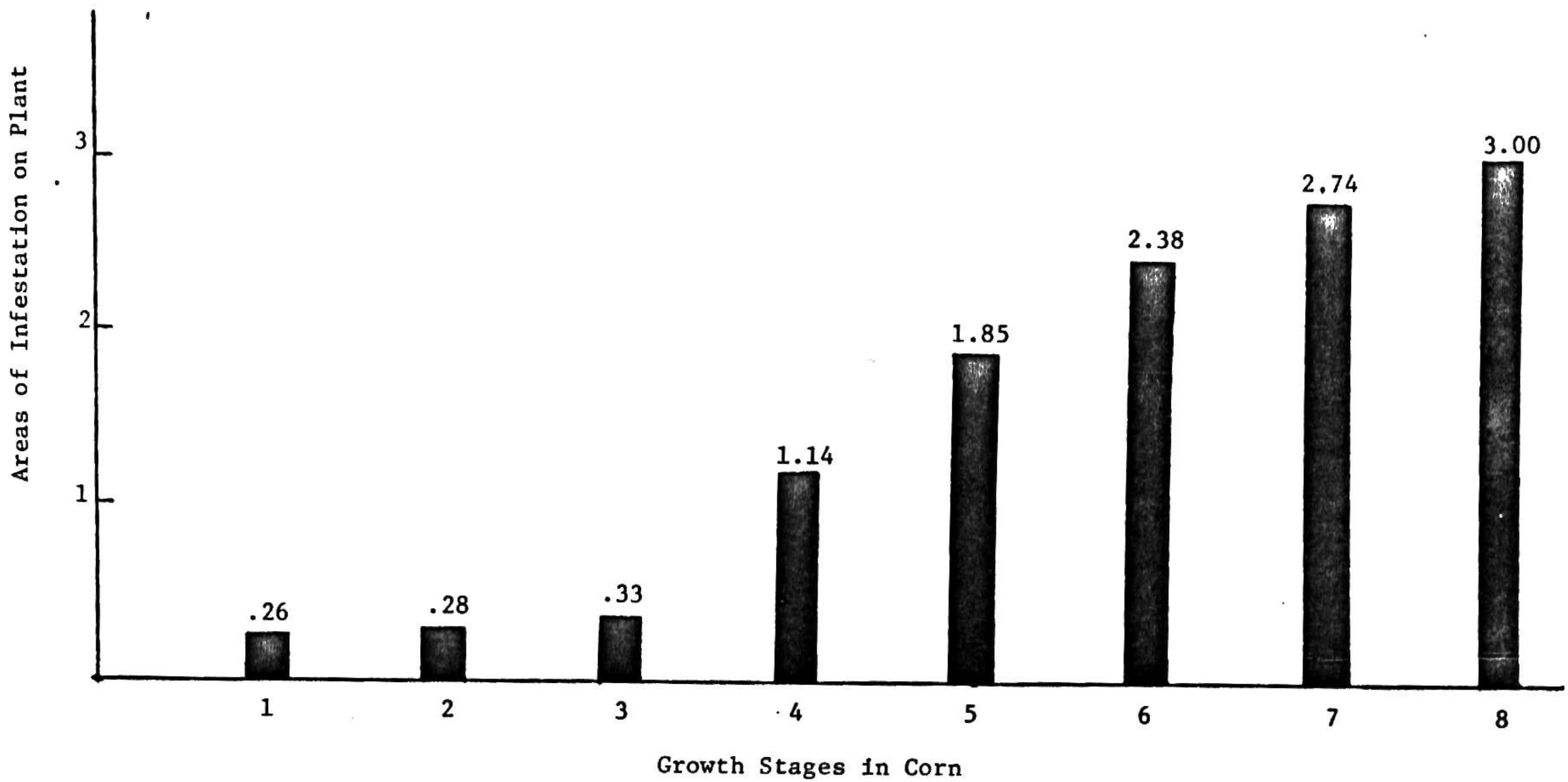

Areas of Infestation on Plant
3
2
1
.26
.28
.33
1.14
1.85
2.38
2.74
3.00
1
2
3
4
5
6
7
8
Growth Stages in Corn

Table 3. Spray dates for corn fields, growth stages and the before versus after spray comparisons of infested leaves, injured leaves and areas of infestations on the plant.

Spray Date	Field Number	Growth Stage	Infested Leaves Before	Infested Leaves After*	Injured Leaves Before	Injured Leaves After*	Area of Plant Before	Area of Plant After*
7/14	21-101	5	1.4	2.5	.3	1.2	1	1
7/14	21-102	5	2.9	3.5	.5	1.5	1	1
7/14	21-103	5	4.1	3.9	1.8	2.0	2	2
7/21	11-101	5	3.7	5.0	1.6	2.6	1	2
7/21	11-102	5	3.8	7.1	2.0	3.4	1	3
7/21	31-101	6	7.4	8.0	4.7	4.0	2	3
7/21	31-102	6	7.5	8.0	4.2	4.0	2	3
7/21	31-103	5	7.0	8.5	4.2	4.5	2	3
7/21	31-103	5	9.1	7.0	5.0	4.5	2	3
7/21	15-101	5	4.6	4.7	1.2	1.0	1	1
7/21	15-103	5	3.2	4.0	.8	.8	1	1
7/21	02-106	5	5.7	9.9	1.8	1.3	2	3
7/24	52-103	5	7.9	8.7	2.7	2.9	2	3
7/27	02-103	5	5.9	8.6	2.7	1.0	2	3
7/27	02-102	5	6.3	8.3	2.5	1.3	2	3
7/29	43-105	5	3.9	5.9	.9	1.1	1	3
7/29	43-106	6	3.5	6.3	.6	1.3	1	3
7/30	14-101	5	6.5	6.0	3.1	1.1	2	2
7/30	14-102	5	4.2	6.5	2.1	2.5	2	2
7/30	14-104	6	7.5	8.0	3.2	3.0	3	3
7/30	15-101	6	6.2	8.5	3.3	2.9	2	3
7/30	15-101	6	6.2	8.5	3.3	2.9	2	3
8/3	48-103	6	8.3	9.1	2.6	3.0	2	3
8/3	48-102	6	8.1	8.3	2.0	2.1	3	3
8/5	04-101	6	9.8	9.0	1.6	2.8	3	3
8/5	04-102	6	9.9	9.7	1.8	3.9	3	3
8/5	04-103	6	8.4	8.9	.7	2.1	3	3
8/9	15-102	6	6.2	8.5	3.3	2.9	2	3
8/9	15-103	6	8.5	8.9	2.9	3.7	3	3
8/11	08-101	7	5.8	6.0	2.8	2.6	2	2
8/11	08-102	7	5.0	5.4	2.1	2.3	2	2

* Time lag after spray application and reentry into fields for recording ranged from 4-7 days.

gallons of water carrier per acre. Disulfoton and Dimethoate were the acarcides used most frequently in the applications. Field observations with hand lens indicated that the chemicals produced a kill on all emerged states of the spider mites. Close examination of the table indicates that the number of infested and injured leaves continued to increase in several cases after spray was applied. The most significant observation is the increase in spread over the plant after the spray was applied.

In the 30 cases of chemical application to corn, increases in spread from the bottom third of the plant to the top two-thirds was noted in 15 fields. Assuming kill was accomplished, it appears that the surviving spider mites and those that hatched from eggs which were abundant at the time of application, spread to other areas of the plant and resumed feeding. Re-infestation could have occurred from adjacent fields; however, since the time interval from spray to resumption of infestation was limited to 7 days, local re-establishment of resident populations is more probable. Spraying was accomplished from first silk through dough stage. This coincides with growth stages 5, 6 and 7 which relates to the high levels of infestation in Figures 3 and 4. Generally, the older the corn the more problems encountered in control according to observations made during the growing season. Low gallonage per acre of carrier may have been insufficient to cover the foliage area of mature corn plants, thus adding to control problems.

Assessment-of the fields not sprayed in the program indicated varying levels of infestations. A higher frequency of infestation levels moving into the upper two-thirds of the plant during stages 5 and 6 was noted. The observations lessen the significance of spray influencing the spread and suggest that the maturity stage of the plant is more dynamic on the influence of population increase and spread than the impact of chemicals.

In pursuing the effects of plant physiology and structure on mite population, correlations were attempted using the Pearson method to determine any differences between varieties. No significant differences were noted between the 25 varieties evaluated and mite infestation levels. Variations between management, irrigation and planting dates reduced the potential of obtaining reliable comparisons. The large number of varieties used in the fields further prevented correlating any significant number of occurrences. However, side by side field comparisons indicated differences between varieties existed under identical culture and management. More extensive evaluations under stable conditions are needed to determine the effect of variety resistance.

Correlations were also attempted between sprinkler and flood irrigation methods. The effect of sprinkler systems providing overhead washing action was thought to have a potential for reducing mite spread and reproduction. Analysis of the information revealed no significant difference between the two irrigation methods. The small number of sprinkler systems in the comparison could reduce the effectiveness of the evaluation. Physical comparisons of infestation levels, injury ratings and areas of infestation revealed similar results in individual field evaluations between the systems. Number of spray applications and timing of treatment produced no additional means of separation of sprinkler and flood irrigation practices.

Limited observations of drought stress influencing mite population was noted during the summer but no field information was gathered. Irrigation techniques utilized by growers prevented any accurate determination of water application per field. In addition, no method was available to evaluate water stress induced by near drought conditions in the area. However, general observations during the peak water use periods of silking, tasseling and grain formation, revealed mite populations were increasing. The heavy infestations appeared to follow water demand on the plant in relation to maturity stages. Extreme temperatures and hot winds induced water stress during these periods regardless of irrigation scheduling. Some increases in infestation were observed to follow irrigation and could not be explained on the basis of present knowledge.

General observations of the 55 fields in the pest management program included increased number of small shriveled ears and poor grain development. Stalk rot was prevalent in many of the fields having heavy infestations of spider mites. Premature drying of the plant was noted in fields having both small ears and symptoms of stalk rot. Weather conditions or severe mite feeding or any combination of both have the potential to induce the symptoms observed. Desiccation and resulting stress produced by mites and their relation to stalk rot is often documented but not understood. Hot dry weather may well have been the deciding influence with mites the secondary suppressor.

Similar analogy can be used to explain poor ear development. The plants' inability to keep pace with water demand under hot dry conditions would be enhanced by the tissue damaging action of the spider mite. Interrelationships of maturity levels, weather conditions and spider mite feeding need to be carefully screened by experimental procedure before assumptions can be made on their individual impact on corn production.

The extent of spider mite infestations per field produced contrary results to observations encountered in previous years. Infestations were found to spread immediately throughout a corn field once populations established themselves rather than limit their feeding to spots or areas. Normally, mites in the region would concentrate their activities in one or two general areas of a field. Hot, dry weather inducing water stress conditions on entire fields during the same period may account for the widespread infestation per field.

Discussion

Field observations recorded on corn fields in Haskell County revealed significant correlations of maturity with mite damage. Both infested leaves and injured leaves increased as corn advanced in maturity. The most significant increase was on infested leaves in stages 5, 6 and 7 corresponding to first silk through dough stage. Maturity ranges inducing mite increases were comparable with the results of H. D. Freese (unpublished data). Populations were significantly higher on tasseled and silked corn. Injured leaves followed a similar pattern. However, degree of injury never matched the extent of infestation.

Increased levels of mite population in relation to growth stages were further established by field reports when areas of infestation on the plant were considered. Stages 5, 6 and 7 involved populations moving into the upper two-thirds of the plant with increasing damage reported. Spreading of the mites into the upper portions of the plant and throughout the corn fields stimulated growers to increase spray activities. Chemical applications were accomplished during the same growth stages with limited effectiveness in reducing population spread in the later maturity ranges.

No correlations could be derived from the planting date groupings observed in 1974. The results did not coincide with studies by Schweissing (1969) in Eastern Colorado in which medium maturity varieties planted late encountered less mite infestation. Further correlations were attempted on the effect of varieties on mite populations in Haskell County. Comparisons on sprinkler versus flood were included in the study. No significant determinations were gained on either comparison.

During the season, general observations were made on incidences of inadequate ear size and development as well as the extent of stalk rot. Both ear quality and stalk rot infestations were noted in the field observations but adequate determination of the relationship to mite infestation could not be made. Attention needs to be focused in areas of interrelationship of corn maturity and mite infestation levels. The separation of the two would enable an assessment of their involvement with water stress, variety resistance and stalk rot.

CONCLUSION

Losses in corn production resulting from spider mite infestations have been observed in Southwest Kansas. The economic threshold of damage has not been established so that growers know at what levels of infestation control must be initiated. Field observations gathered in Haskell County have not indicated severe photosynthetic loss due to the destruction of leaves. Moderate levels of discoloration and desiccation, resulting in injury to the plant, were limited to an overall average for the 47 fields of 3.15 destroyed leaves per plant. Due to the lack of knowledge of how many leaves a corn plant can lose before production potential is reduced and to what extent further leaf loss would occur, 31 of the fields were chemically treated. The majority of research completed on corn supports the concept that chemical treatment can produce significantly greater yields (Bacon et al., 1962; Ward et al., 1972; Schweissing, 1973). However, level of infestation, stage of maturity and chemical application timing was not elaborated on by these investigators. The need for more specific experimentation on economic thresholds of chemical application is evident.

Economically orientated research must be directed toward the effects of corn on spider mite infestations in order to maximize efforts to control the pest. Examination of the literature produced a substantial number of workers reporting the interrelationship of the physiology of the host plant and mite populations. The biology of the three species of mites further substantiates the relation of plant hosts to mite production. Feeding habits, reproduction requirements, dispersal and alternate plant hosts of the *Oligonychus pratensis*, *Tetranychus urticae* and *Tetranychus cinnabarinus* are similar when involving agronomic dimensions. The maturity of the corn plant continually becomes involved in the assessment of mite potential both in the review and in the field observations. It was established by some investigators that the plant nutrients complement each other in stimulating mite production, particularly nitrogen and phosphorus. The assumption was made that nutrients were only the catalyst, with carbohydrates formed from the increased absorption being the inducement for mite increase. Physiological maturity was determined to be a limiting factor in infestation and injury levels under field inspection which further adds to this phenomenon.

Water stress on the plant adds another ramification to the plant-mite complex. Heaviest mite infestations were reported on corn under water stress conditions imposed by hot dry weather. Under drought conditions photosynthesis was determined to be impaired and carbohydrate transfer was slowed, causing a carbohydrate buildup in cells of leaves. Further accumulation of salts in cell vacuole was indicated by investigations. Carbohydrate accumulation or salt increase in cells occurs during water stress in conjunction with increased mite feeding and reproduction. In support of results noted by other workers, field observations in Haskell County indicated increased feeding activities of spider mites during the hot, dry conditions of 1974.

No conclusive evidence has been furnished regarding the related effects of stalk breakage and poor ear development under conditions of severe mite damage. The observations made in Southwest Kansas serve only to record further occurrences of increased stalk rot and the associated small, "loose" ear development. Repeated field reports of stalk rot and small ears evident in fields having mite infestations support the assumption that a relationship exists. The extent of spider mite influence on the initiation or development of pathogens in the corn stalk is not understood. The symptoms may be explained on the basis of accompanying hot, dry weather which induces development with spider mite injury furnishing the mode of entry.

Natural controls are imperative in designing a spider mite control program. The influence of weather on both plant physiology and mite development provides the single most limiting factor. Since no control can be imposed on weather conditions, the grower must design his cultural practices, variety selection and predator action so they are enhanced by the single factor. Response was reported on using later planting dates to retard mite population. No correlations were noted in the field observations on planting dates. Variety resistance was observed by Schweissing (1973) and limited observations were made in the field inspections on the existence of the factor. No particular varieties have been singled out. Spider mite reduction by predators has been reported by several investigators, particularly the destructive action of the Scolothrips sexamaculatus. However, predators were found to fluctuate with prey and successful attempts to initiate populations have been limited.

Much of the present knowledge of spider mite bionomics were the result of chemical control studies. The literature continues to emphasize the physiological relationship of the plant to mite density resulting from chemical application. Increased populations of T. urticae and T. cinnabarinus have been reported in the absence of predators after treatment of either DDT, carbaryl, parathion, aldrin, chlordane, lindane or dieldrin, thus demonstrating a physiological plant action for this phenomenon. Investigators have revealed that both parathion and carbaryl disrupt the plant-nutrient ratios which in turn induces an increase of reducing sugars, favorable to mite production (Henneberry, 1964; Rodriguez, Chen and Smith, 1960; Klostermeyer and Rasmussen, 1953). The carbohydrate to sugar stimulation is comparable to the results of water stress effects on the plant.

Many workers still support the action of chemicals reducing natural enemies which enhances the production potential of the spider mite. Numerous observations on the three species report a greater degree of dispersal to enemy-free leaf surfaces and a resumption of feeding following destruction of predators. The presence of resistance strains to pesticides has been established in T. urticae. Chemical resistance has been noted to be increasing in O. pratensis on irrigated corn. The complexity of chemical treatment on host plant physiology, predator populations and resistance development must be examined thoroughly in order to effectively isolate any potential they may offer in an integrated control program.

In order to provide the growers with a practical means of control, utilizing all available resources to reduce spider mite populations, a considerable amount of research is needed. Prior studies have indicated that the potential to reduce numbers by natural controls without chemicals is possible. At least an integrated program would reduce the need for repeated spray applications and slow the development of resistant strains. Field observations have substantiated the need for an agronomic approach to mite control. The physiology of the plant is related to spider mite development and offers an alternate approach to reducing the spider mite threat to corn production in Southwest Kansas.

ACKNOWLEDGMENTS

The author wishes to express his sincere gratitude to his major professor, Dr. Iwan D. Teare, for his patience and assistance in preparing the report.

Appreciation is also extended to members of the supervisory committee, Dr. Harold E. Jones and Dr. Stanley W. Ehler, for their guidance and support in the preparation of the study. A special acknowledgment is extended to committee consultants, Dr. Jay D. Stone, for his advice on spider mite biology and Dr. Donald E. Mock, for his help in the pest management project.

Lasting gratitude is expressed to the writer's wife, Pauline, for her patience and help in preparing the manuscript.

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VITA

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In 1962 the author married Pauline L. Schweitzer. Two sons have resulted from the marriage, Jeffery M. Radke and Jerry John Radke.

A P P E N D I X

Field Reports on Corn Development and Spider Mite Populations
by Field: Observations at regular intervals

Field Number	Date	Growth Stage	Area of Field	Average no. of Leaves: Live	Average no. of Leaves: Infested	Average no. of Leaves: Injured	Average no. of Leaves: Dead	Area of Plant	Spray Date
02-101	7/3	3	3	6.7	1.2	0	0	0	None
F	7/10	3	3	8.0	2.1	.1	0	0	"
	7/16	3	3	12.6	2.3	0	0	0	"
	7/22	5	3	14.5	4.3	1.0	0	1	"
	7/31	6	3	14.3	6.3	1.0	.2	2	"
	8/7	7	3	14.3	7.3	1.1	.6	3	"
	8/14	7	3	14.3	9.1	1.4	.6	3	

Plant Pop.- Planting Date--May 10; Acres--55; Variety--3306;
Irrigation--Flood; Yield--150

Field Number	Date	Growth Stage	Area of Field	Live	Infested	Injured	Dead	Area of Plant	Spray Date
02-102	7/3	3	3	7.0	1.1	0	0	0	7/27
	7/10	3	3	8.3	1.8	.3	0	0	"
	7/12	3	3	13.0	2.5	0	0	0	"
	7/16	3	3	13.0	2.5	0	0	0	"
	7/22	5	3	14.4	6.3	2.5	0	2	
	7/31	6	3	14.4	8.3	1.3	.5	3	
	8/7	7	3	14.2	8.7	1.3	.5	3	
	8/14	7	3	14.2	9.3	1.4	.4	3	

Plant Pop.- Planting Date--May 10; Acres--80; Variety--3306;
Irrigation--Flood; Yield--150

Field Number	Date	Growth Stage	Area of Field	Live	Infested	Injured	Dead	Area of Plant	Spray Date
02-103	7/3	3	3	6.9	1.3	0	0	0	7/27
	7/10	3	3	8.3	2.4	.1	0	0	"
	7/16	3	3	12.7	2.2	0	0	0	"
	7/22	5	3	14.4	5.9	2.7	0	2	
	7/31	6	3	14.5	8.6	1.0	.3	3	
	8/7	7	3	14.4	9.0	.9	.3	3	
	8/14	7	3	14.0	9.8	1.0	.9	3	

Plant Pop.- Planting Date--May 8; Acres--50; Variety--3306;
Irrigation--Flood; Yield--150

Field Number	Date	Growth Stage	Area of Field	Average no. of Leaves: Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
02-104	7/3	3	3	8.1	2.0	0	0	0	None
S	7/10	3	3	10.4	3.5	.5	0	0	"
	7/16	3	3	9.3	2.2	0	0	0	
	7/23	5	3	13.6	5.1	0	0	1	
	7/31	6	3	14.4	6.9	1.1	.2	2	
	8/7	6	3	14.5	7.1	1.1	.6	2	
	8/14	7	3	14.5	8.1	1.4	.3	3	

Plant Pop.- Planting Date--May 20; Acres--130; Variety--85;
Irrigation--Sprinkler; Yield--75

Field Number	Date	Growth Stage	Area of Field	Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
02-105	7/3	2	3	5.0	1.0	0	0	0	None
S	7/10	2	3	6.8	2.3	0	0	0	"
	7/16	3	3	11.0	2.2	0	0	0	
	7/23	5	3	13.2	5.7	.9	0	1	
	7/31	6	3	14.3	6.1	1.0	0	2	
	8/8	6	3	14.3	6.1	1.0	.3	2	
	8/14	7	3	14.5	8.1	1.4	.3	3	

Plant Pop.- Planting Date--May 15; Acres--130; Variety-1119;
Irrigation--Sprinkler; Yield--90

Field Number	Date	Growth Stage	Area of Field	Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
02-106	7/3	3	3	5.1	1.0	0	0	0	7/21
F	7/10	3	3	5.9	2.3	0	0	0	"
	7/16	4	3	13.1	2.9	.4	0	0	"
	7/19	5	3	14.1	5.7	1.8	0	2	
	7/31	6	3	14.3	9.9	1.3	.4	3	
	8/7	7	3	14.1	9.9	1.4	.4	3	
	8/14	8	3	14.0	11.0	1.8	.7	3	

Plant Pop.- Planting Date--April 30; Acres--160; Variety--3195, 3306;
Irrigation--Flood; Yield--160

Field Number	Date	Growth Stage	Area of Field	Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
02-107	7/3	3	3	5.0	1.3	0	0	0	None
F	7/10	3	3	6.2	2.4	.2	0	0	"
	7/16	4	3	13.0	2.7	.1	0	0	"
	7/19	5	3	14.3	5.9	1.6	0	1	
	7/31	5	3	14.2	8.6	1.0	.5	3	
	8/7	6	3	14.2	8.7	1.3	.5	3	
	8/14	7	3	13.9	9.1	1.5	.8	3	

Plant Pop.- Planting Date--April 31; Acres--80; Variety--3195, 2685;
Irrigation--Flood; Yield 160

Field Number	Date	Growth Stage	Area of Field	Average no. of Leaves: Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
04-101	6/10	2	3	5.2	.1	0	0	0	
F	6/27	3	3	5.5	.7	0	0	0	
	7/15	4	3	10.1	4.4	.6	0	1	
	7/23	5	3	14.4	5.9	2.3	.8	2	
	7/31	6	3	14.4	9.8	1.6	.4	3	
	8/7	7	3	13.9	9.0	2.8	.6	3	
	8/13	7	3	13.9	9.7	3.2	.8	3	

Plant Pop.- 20,000; Planting Date--May 10; Acres--130; Variety--3306, 3385; Irrigation--Flood; Yield--102

Field Number	Date	Growth Stage	Area of Field	Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
04-102	6/19	2	2	5.4	.05	0	0	0	
	6/27	2	3	5.3	1.20	.15	0	0	
	7/9	3	3	8.9	2.40	0	0	0	
	7/15	4	3	10.4	5.6	2.30	0	2	
	7/22	5	3	12.9	6.4	2.60	.9	2	
	7/31	6	3	14.0	9.9	1.80	.9	3	
	8/7	7	3	14.1	9.7	3.9	1.1	3	
	8/14	7	3	14.2	10.1	4.3	1.4	3	

Plant Pop.- Planting Date--May 10; Acres--107; Variety--2686, 3159; Irrigation--Flood; Yield--18T

Field Number	Date	Growth Stage	Area of Field	Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
04-103	6/27	2	3	5.6	.9	0	0	0	8/5
F	7/9	3	3	9.0	4.1	0	0	0	
	7/16	4	3	14.3	5.8	.9	0	1	
	7/23	5	3	13.8	4.5	1.2	.9	1	
	7/31	5	3	14.5	8.4	.7	0	3	
	8/6	7	3	14.0	8.9	2.1	.4	3	
	8/13	7	3	13.8	9.4	2.9	.9	3	

Plant Pop. Planting Date--May 21; Acres--80; Variety--3306; Irrigation--Flood; Yield--93

Field Number	Date	Growth Stage	Area of Field	Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
06-101	6/10	2	0	6.4	0	0	0	0	None
F	6/19	3	2	5.7	.1	0	0	0	
	6/27	3	3	6.6	.8	0	0	0	
	7/9	4	3	12.7	1.4	.8	0	0	
	7/16	5	2	13.0	.5	.2	0	1	
	7/25	6-7	2	13.0	1.1	.6	0	1	
	7/31	7	3	13.5	3.3	1.4	.8	1	
	8/8	7	3	13.5	3.5	1.1	0	1	

Plant Pop.- 13,500; Planting Date--May 5; Acres--160; Variety--72; Irrigation--Flood; Yield

Field Number	Date	Growth Stage	Area of Field	Average no. of Leaves Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
08-101	6/12	2	2	6.8	.1	0	0	1	8/11
F	6/17	2	3	7.2	.4	.3	0	1	
	7/2	3	1	11.2	.1	0	0	0	
	7/8	3	3	9.3	1.8	.4	0	1	
	7/16	4	0	13.0	0	0	0	0	
	7/24	7	3	13.0	5.8	2.3	0	2	
	7/30	7	3	13.0	5.7	2.3	0	2	
	8/7	7	3	13.5	5.8	2.8	.7	2	
	8/15	7	3	13.5	6.0	2.6	.5	2	

Plant Pop.- 22,000; Planting Date--May 8; Acres--102; Variety--72; Irrigation--Flood; Yield

Field Number	Date	Growth Stage	Area of Field	Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
08-102	6/12	2	2	8.2	.1	0	0	1	8/11
F	6/17	2	2	7.8	.1	0	0	1	
	7/2	3	0	10.3	0	0	0	0	
	7/8	4	3	10.7	.7	.5	0	1	
	7/16	5	1	13.5	.2	0	0	1	
	7/24	7	3	13.0	6.1	3.6	0	2	
	7/30	7	3	13.0	6.4	3.1	0	2	
	8/7	7	3	13.5	5.0	2.1	.9	2	
	8/15	7	3	13.5	5.4	2.3	.4	2	

Plant Pop.- 22,600; Planting Date--April 27; Acres--93; Variety--72; Irrigation--Flood; Yield

Field Number	Date	Growth Stage	Area of Field	Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
09-101	7/2	1	2	6.8	.3	0	0	0	8/5
	7/8	2	0	7.8	0	0	0	0	
	7/17	3	3	9.1	1.3	.4	0	1	
	7/25	3	3	12.5	2.5	1.2	0	1	
	7/30	4	3	12.8	5.3	1.6	0	2	
	8/8	5	0	13.1	0	0	0	0	
	8/12	6	3	14.0	6.0	2.6	.6	2	

Plant Pop.- Planting Date--May 20; Acres--110; Variety--77; Irrigation--Flood; Yield--100

Field Number	Date	Growth Stage	Area of Field	Average no. of Leaves: Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
09-102	7/2	1	0	5.5	0	0	0	0	8/5
	7/8	2	0	7.9	0	0	0	0	
	7/17	3	0	9.6	0	0	0	0	
	7/25	4	3	12.0	3.1	2.1	0	1	
	7/30	4	3	11.5	4.1	1.8	0	2	
	8/8	5	0	12.6	0	0	0	0	
	8/12	6	3	13.6	4.5	2.0	0	0	
Plant Pop.-	Planting Date--May 20; Acres--90; Variety--372, 255; Irrigation--Flood; Yield--100								
11-101	6/17	1	2	5.6	.2	0	0	1	7/21
	7/2	1	3	6.7	.8	.4	0	0	
	7/8	3	3	8.9	1.0	.6	0	1	
	7/17	4	3	11.9	3.7	1.6	0	1	
	7/22	5	3	14.0	5.0	2.5	0	2	
	7/30	6	3	14.0	5.2	2.6	0	2	
	8/8	7	3	13.5	5.5	2.4	1.1	2	
	8/13	7	3	13.5	5.8	2.1	1.3	2	
Plant Pop.-	Planting Date--May 9; Acres--48; Variety--12; Irrigation--Flood; Yield--20T Silage								
11-102	6/17	1	0	3.0	0	0	0	0	7/21
	7/2	1	3	5.7	.6	.2	0	0	
	7/8	2	3	7.9	1.2	.4	0	1	
	7/17	3	3	9.1	3.8	2.0	0	1	
	7/22	5	3	12.0	7.1	3.4	0	3	
	7/30	7	3	12.0	7.2	3.4	0	3	
	8/8	7	3	13.0	7.1	3.7	1.8	3	
	8/13	7	3	11.8	6.8	3.6	2.1		
Plant Pop.-	Planting Date--May 11; Acres--80; Variety--255; Irrigation--Flood; Yield--155								
14-101	7/2	2	3	8.8	1.0	.3	0	0	7/30
	7/9	2	3	8.7	2.5	1.6	0	1	
	7/16	3	3	11.0	6.4	3.8	0	3	
	7/22	4	3	10.0	6.5	3.1	1.3	2	
	8/9	6	0	13.0	0	0	0	0	
	8/13	6	0	13.0	0	0	0	0	
Plant Pop.-	Planting Date--May 12; Acres--77; Variety--49; Irrigation--Flood; Yield--120								

Field Number	Date	Growth Stage	Area of Field	Average no. of Leaves: Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
14-102	7/2	2	3	7.4	.8	.1	0	0	7/30
	7/9	3	3	10.5	1.6	1.0	0	1	
	7/16	3	3	11.4	2.2	1.1	0	1	
	7/22	4	3	12.0	4.2	2.1	0	2	
	8/9	5	3	13.0	6.5	2.5	0	2	
	8/13	6	3	12.0	6.5	2.5	1.2	2	
Plant Pop.-		Planting Date--May 15; Acres--74; Variety--72; Irrigation--Flood; Yield--120							
14-103 F	7/2	3	0	9.6	0	0	0	0	7/30
	7/9	1	0	5.7	0	0	0	0	
	7/16	2	0	7.0	0	0	0	0	
	7/22	2	0	8.0	0	0	0	0	
	8/9	4	3	12.5	2.1	1.0	0	1	
	8/13	4	3	12.5	2.0	1.0	0	1	
Plant Pop.-		Planting Date--June 16; Acres--56; Variety--372; Irrigation--Flood; Yield--16 1/2 T							
14-104 F	7/2	2	3	8.3	.7	.2	0	0	7/30
	7/9	3	3	11.5	4.5	2.6	.1	1	
	7/16	4	3	11.6	5.6	3.0	0	2	
	7/22	5	3	13.0	7.5	3.2	1.6	3	
	8/9	7	0	13.5	8.0	0	0	0	
	8/13	7	3	13.0	8.0	4	1	3	
Planting Pop.-		Planting Date--May 18; Acres--24; Variety--374; Irrigation--Flood; Yield--120							
15-101	6/19	2	0	4.7	0	0	0	0	7/21
	6/25	3	3	5.9	.2	0	0	0	7/30
	7/9	3	3	8.7	2.1	.3	0	0	
	7/15	5	3	13.5	4.4	1.3	0	0	
	7/18	5	3	14.1	4.6	1.2	0	1	
	7/24	6	3	14.1	4.7	1.0	0	1	
	7/30	6	3	12.1	6.2	3.3	1.1	2	
	8/7	6	3	14.0	8.5	2.9	.3	3	
	8/12	8	3	11.6	9.2	4.0	1.7	3	
Plant Pop.-		Planting Date--May 15; Acres--113; Variety--3369, 3390; Irrigation--Flood; Yield--105							

Field Number	Date	Growth Stage	Area of Field	Average no. of Leaves: Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
15-102	6/19	1	2	3.9	.1	0	0	0	7/21
	6/25	2	3	5.0	.2	0	0	0	& 8/9
	7/9	3	3	6.3	.8	0	0	0	
	7/15	3	3	8.7	2.6	1.1	0	0	
	7/18	3	3	14.1	4.6	1.2	0	1	
	7/24	3	3	13.3	3.3	.7	0	1	
	7/30	5	3	14.0	5.8	2.7	.8	2	
	8/7	6	3	14.1	7.3	3.1	1.0	3	
	8/12	7	3	13.9	7.9	4.0	1.0	3	
Plant Pop.-	Planting Date--May 30; Acres--187; Variety--72, 3306, 3149, 3388; Irrigation--Flood; Yield--106								
15-103	6/19	2	0	4.7	0	0	0	0	7/21
	6/25	3	3	5.2	.3	0	0	0	8/9
	7/9	3	3	8.5	1.0	.1	0	0	
	7/15	4	3	11.9	3.2	.8	0	1	
	7/24	5	3	14.3	4.6	.8	0	1	
	7/30	5	3	14.3	5.9	2.8	0	2	
	8/7	6	3	14.0	8.5	2.9	.3	3	
	8/12	7	3	13.9	8.9	3.7	.8	3	
Plant Pop.-	Planting Date--May 20; Acres--80; Variety--3390, 370, 72; Irrigation--Flood; Yield--109								
21-101	6/10	2	2	6.4	.1	0	0	0	7/14
	6/19	3	3	6.2	.1	0	0	0	
	6/27	3	3	6.8	.8	0	0	0	
	7/9	4	3	11.6	1.4	.3	0	1	
	7/16	5	0	14.0			0	0	
	7/25	6	3	13.5	2.5	1.2	0	1	
	7/31	7	3	13.5	4.5	2.4	1.3	1	
	8/8	7	3	13.5	4.5	2.1	0	2	
	8/15	7	2	13.5	7.5	3.5	.8	3	
Plant Pop.-	Planting Date--April 29; Acres--78; Variety--3195; Irrigation--Flood; Yield--174								

Field Number	Date	Growth Stage	Area of Field	Average no. of Leaves: Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
21-102	6/10	2	3	6.2	.3	0	0	0	7/14
	6/19	3	3	6.1	.15	0	0	0	
	6/27	3	3	7.2	1.70	0	0	0	
	6/9	4	3	16.5	2.90	.5	0	1	
	7/16	5	0	13.0	0	0	0	0	
	7/25	6	3	12.5	3.5	1.5	0	1	
	7/31	7	3	13.2	3.5	1.1	0	1	
	8/8	7	3	13.5	2.4	1.1	0	1	
	8/15	7	2	13.5	5.5	2.2	0	2	
Plant Pop.- 26,000; Planting Date--April 27; Acres--156; Variety--3169, 3306; Irrigation--Flood; Yield--172, 161									
21-103	6/10	2	3	6.7	.3	0	0	0	7/14
	6/19	3	3	6.1	.75	0	0	0	
	6/27	3	3	7.1	1.20	0	0	0	
	7/9	5	3	13.5	4.10	1.8	0	2	
	7/16	5	0	14.0	0	0	0	0	
	7/25	6	0	13.0	0	0	0	0	
	7/31	7	3	13.5	3.9	2.0	0	1	
	8/8	7	3	13.5	2.4	1.1	0	1	
	8/15	7	3	13.5	3.5	1.1	0	1	
Plant Pop.- 24,800; Planting Date--April 23; Acres--150; Variety--255, 3195; Irrigation--Flood; Yield--146, 178									
31-101	6/12	1	3	6.1	1.4	1.7	0	1	7/21
F	6/18	3	3	8.5	2.5	.7	.1	1	
	6/24	3	3	10.3	2.1	.3	.1	1	
	7/3	3	3	11.6	3.4	2.0	.3	1	
	7/12	5	3	12.8	7.4	4.7	.1	2	
	7/25	6	3	14.0	8.0	4.0	1.8	3	
	7/30	7	3	14.0	8.0	4.0	1.8	3	
	8/9	7	3	13.5	8.0	4.0	1.8	3	
	8/13	7	3	13.5	7.5	2.8	1.0	3	
Plant Pop. Planting Date--May 3; Acres--60; Variety--72; Irrigation--Flood; Yield--150									

Field Number	Date	Growth Stage	Area of Field	Average no. of Leaves: Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
31-102	6/12	1	3	5.6	1.7	.9	0	1	7/21
F	6/18	2	3	9.0	2.5	.2	0	1	
	6/24	3	3	10.9	1.4	.2	0	1	
	7/3	3	3	11.6	4.7	3.6	.5	2	
	7/12	4	3	12.6	7.5	4.2	.2	3	
	7/25	6-7	3	13.0	8.0	4.0	2.0	3	
	7/30	7	3	13.0	8.0	4.0	2.0	3	
	8/9	7	3	13.0	8.0	4.5	2.3	3	
	8/13	7	3	12.5	8.0	3.5	1.1	3	

Plant Pop.- Planting Date--May 2; Acres--60; Variety--2530, 85; Irrigation--Flood; Yield--150

Field Number	Date	Growth Stage	Area of Field	Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
31-103	6/12	1	3	5.6	.3	0	0	1	7/21
	6/18	2	3	8.4	1.6	.3	.3	1	
	6/24	3	3	10.9	1.6	.1	0	1	
	7/3	3	3	11.2	1.6	.8	.1	1	
	7/12	4	3	12.0	.7	4.2	.1	2	
	7/25	6-7	3	14.0	8.5	4.5	2.3	3	
	7/30	7	3	13.0	7.0	3.5	2.0	3	
	8/9	7	3	13.0	8.0	5.0	2.5	3	
	8/13	7	3	13.0	9.0	4.5	1.5	3	

Plant Pop.- Planting Date--May 7; Acres--75; Variety--119, 255; Irrigation--Flood; Yield--95, 100

Field Number	Date	Growth Stage	Area of Field	Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
31-104	6/12	2	3	7.1	1.6	1.1	0	1	7/21
	6/18	2	3	8.4	1.8	.3	0	1	
	6/24	3	3	8.5	1.8	.1	.1	1	
	7/3	3	3	12.7	5.2	3.9	.6	1	
	7/12	4	3	12.8	9.1	5.0	0	2	
	7/25	6-7	3	13.0	7.0	3.5	2.0	3	
	7/30	7	3	13.0	7.0	3.5	2.6	3	
	8/9	7	3	13.0	7.0	4.5	2.1	3	
	8/13	7	3	13.5	8.5	4.0	1.2	3	

Plant Pop.- Planting Date--April 25; Acres--191; Variety--110, 2500, 7; Irrigation--Flood; Yield--200, 135

Field Number	Date	Growth Stage	Area of Field	Average no. of Leaves Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
43-101	6/11	1	0	4.2	0	0	0	0	None
F	6/20	1	1	4.5	.1	0	0	0	
	7/1	2	3	5.5	.7	0	0	0	
	7/10	2	3	7.1	3.3	.2	0	0	
	7/16	3	3	7.1	3.3	.7	0	0	
	7/23	4	3	12.7	5.1	.7	0	1	
	7/31	5	3	13.9	7.9	1.1	0	3	
	8/6	6	3	13.9	8.4	1.9	0	3	
	8/14	7	3	14.1	9.1	2.8	.4	3	

Plant Pop.- 24,000 Planting Date--May 21; Acres--180; Variety--3149; Irrigation--Flood; Yield--135

Field Number	Date	Growth Stage	Area of Field	Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
43-102	6/11	2	0	6.2	0	0	0	0	None
F	6/20	3	3	5.2	.05	0	0	0	
	7/1	3	3	7.6	1.20	0	0	0	
	7/9	4	3	8.4	3.1	.3	0	1	
	7/15	5	3	14.5	6.1	1.3	0	2	
	7/23	5	3	14.0	6.7	2.2	.2	2	
	7/31	7	3	14.0	9.1	2.9	.7	3	
	8/6	7	3	14.1	9.0	3.2	.7	3	
	8/14	7	3	13.8	9.9	3.9	1.1	3	

Plant Pop.- 21,750; Planting Date--April 24; Acres--160; Variety--3195; Irrigation--Flood; Yield--130

Field Number	Date	Growth Stage	Area of Field	Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
43-103	6/11	0	1	3.2	.5	0	0	0	None
	6/20	1	1	4.2	.15	0	0	0	
	7/1	2	3	5.3	.70	0	0	0	
	7/9	2	3	5.9	1.50	0	0	0	
	7/15	3	3	6.8	2.7	.4	0	0	
	7/23	4	3	13.2	5.0	.5	0	1	
	7/31	5	3	13.8	8.3	2.2	0	3	
	8/6	5	3	14.0	8.4	3.3	.3	3	
	8/14	6	3	14.4	9.9	3.8	.8	3	

Plant Pop.- Planting Date--May 27; Acres--108; Variety--3390; Irrigation--Flood; Yield--60 Hailed

Field Number	Date	Growth Stage	Area of Field	Average no. of Leaves: Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
43-104	6/11	1	0	3.7	0	0	0	0	None
	6/20	2	1	4.6	0.15	0	0	0	
	7/1	3	3	6.8	1.7	0	0	0	
	7/9	3	3	8.2	4.4	.7	0	0	
	7/15	3	3	9.9	5.3	2.2	0	0	
	7/23	5	3	14.5	5.9	1.1	0	1	
	8/1	6	3	14.1	9.1	2.5	.5	3	
	8/7	7	3	14.0	9.1	2.9	.8	3	
	8/14	7	3	14.0	10.8	3.9	1.2	3	

Plant Pop.- 21,100; Planting Date--May 1; Acres--170; Variety--3149;
Irrigation--Flood; Yield--135

Field Number	Date	Growth Stage	Area of Field	Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
43-105	6/12	1	2	4.3	.2	0	0	0	7/29
S	6/18	2	2	5.1	.1	0	0	0	
	7/1	3	3	6.7	.9	0	0	0	
	7/16	3	3	9.2	3.6	.0	0	0	
	7/23	4	3	13.9	3.9	.9	0	1	
	8/1	5	3	13.9	5.9	1.1	.9	3	
	8/7	5	3	13.9	6.2	1.8	1.1	3	

Plant Pop.- 23,000; Planting Date--May 15; Acres--130; Variety--3366;
Irrigation--Sprinkler; Yield--125

Field Number	Date	Growth Stage	Area of Field	Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
43-106	6/12	2	2	6.0	.25	0	0	0	7/29
S	6/18	2	2	5.3	.15	0	0	0	
	7/1	3	3	6.8	1.10	0	0	0	
	7/10	3	3	9.9	2.40	0	0	0	
	7/16	3	3	9.6	3.10	.6	0	1	
	7/23	5	3	14.1	3.50	.6	0	1	
	8/1	6	3	14.0	6.30	1.3	.7	3	
	8/13	7	3	13.7	8.7	3.3	1.4	3	

Plant Pop.- 24,500; Planting Date--May 9; Acres--130; Variety--3366, 2685
Irrigation--Sprinkler; Yield--130

Field Number	Date	Growth Stage	Area of Field	Average no. of Leaves: Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
47-101	6/11	1	2	4.7	0	0	0	0	None
S	6/19	2	2	4.5	.05	0	0	0	
	6/25	2	3	4.9	.15	0	0	0	
	7/8	3	3	6.4	1.30	0	0	0	
	7/17	3	3	9.8	2.70	0	0	0	
	7/24	4	3	11.3	4.90	1.0	0	1	
	7/30	6	3	12.1	6.10	1.3	0	2	
	8/8	6	3	12.3	6.3	1.5	.5	2	
	8/12	6	3	12.1	8.1	2.9	.8	3	
Plant Pop.- 22,000; Planting Date--May 16; Acres--130; Variety--1119, 2685; Irrigation--Sprinkler; Yield--70									
47-102	6/11	1	2	4.5	0	0	0	0	None
F	6/19	1	2	4.2	.1	0	0	0	
	6/25	2	3	4.9	.15	0	0	0	
	7/8	3	3	5.8	1.10	0	0	0	
	7/17	3	3	8.2	.34	0	0	0	
	7/24	3	3	9.7	5.1	.8	0	0	
	7/30	5	3	13.9	5.7	2.0	0	2	
	8/8	6	3	13.8	6.1	2.1	.3	2	
	8/12	7	3	13.9	8.9	3.2	.7	3	
Plant Pop.- 20,500; Planting Date--May 19; Acres--10; Variety--3385, 3366; Irrigation--Flood; Yield--150									
48-101	6/12	2	2	4.3	.2	0	0	0	None
F	6/19	2	3	5.7	0.5	0	0	0	
	7/2	3	3	8.1	1.6	.2	0	0	
	7/10	3	3	10.9	1.8	.6	0	0	
	7/16	5	3	12.1	3.3	.9	0	1	
	7/22	5	3	13.4	3.9	.8	0	1	
	8/1	6	3	13.5	7.2	.9	0	2	
	8/7	7	3	13.4	8.1	1.8	0	3	
	8/13	7	3	13.1	8.7	1.9	.4	3	
Plant Pop.- Planting Date--May 8; Acres--50; Variety--2500, 97; Yield--100; Irrigation--Flood									

Field Number	Date	Growth Stage	Area of Field	Average no. of Leaves: Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
48-102	6/12	1	2	4.3	.2	0	0	0	8/3
F	6/19	1	3	4.9	.1	0	0	0	
	7/2	3	3	7.9	2.3	0	0	0	
	7/10	3	3	9.6	4.1	1.9	0	0	
	7/16	3	3	9.8	4.0	1.0	0	0	
	7/22	4	3	10.7	5.9	2.9	.7	2	
	8/1	5	3	12.3	8.1	2.0	0	3	
	8/7	6	3	12.7	8.3	2.1	0	3	
	8/13	7	3	12.8	8.9	2.9	.7	3	
Plant Pop.-	Planting Date--May 15; Acres--100; Variety--100, 2500; Irrigation--Flood; Yield--45								
48-103	6/12	2	2	5.3	.1	0	0	0	8/3
F	6/19	2	3	5.1	.15	0	0	0	
	7/2	3	3	8.4	1.4	0	0	0	
	7/10	4	3	11.0	2.1	.5	0	1	
	7/16	5	3	14.3	4.6	1.1	0	1	
	7/22	5	3	13.9	6.4	2.7	.6	2	
	8/1	6	3	13.9	8.3	2.6	.8	2	
	8/7	7	3	13.9	9.1	3.0	.8	3	
	8/13	8	3	13.7	9.7	3.7	1.0	3	
Plant Pop.-	Planting Date--May 7; Acres--45; Variety--12; Irrigation--Flood; Yield--153								
48-104	6/12	1	2	4.8	.15	0	0	0	None
F	6/19	2	3	5.1	.10	0	0	0	
	7/2	3	3	7.7	1.3	.0	0	0	
	7/10	3	3	9.8	1.9	.2	0	0	
	7/16	4	3	13.3	3.7	.7	0	1	
	7/22	5	3	10.9	4.7	1.1	.3	1	
	8/1	6	3	11.2	7.7	1.3	0	2	
	8/7	7	3	11.8	7.9	1.7	.3	3	
	8/13	7	3	11.8	8.4	2.3	.8	3	
Plant Pop.-	Planting Date--May 14; Acres--80; Variety--5555; Irrigation--Flood; Yield--80								

Field Number	Date	Growth Stage	Area of Field	Average no. of Leaves: Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
49-101	7/2	3	3	9.0	1.7	0	0	0	None
F	7/10	3	3	11.1	2.2	1.0	0	0	
	7/16	5	3	13.2	4.6	2.4	0	1	
	7/25	6-7	3	13.0	6.5	3.2	1.1	2	
	7/31	7	3	13.5	6.5	3.2	1.4	3	
	8/8	7	0	13.5	0	0	0	0	
	8/15	7	3	13.5	6.5	2.8	1.0	2	

Plant Pop.- Planting Date--May 14; Acres--160; Variety--372; Irrigation--Flood; Yield

Field Number	Date	Growth Stage	Area of Field	Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
50-101	6/12	2	2	7.3	.4	0	0	1	None
F	6/20	2	0	7.8	0	0	0	0	
	6/27	2	0	8.8	0	0	0	0	
	7/3	3	2	11.8	.2	0	0	1	
	7/15	4	3	13.1	5.7	3.7	0	1	
	7/22	5	3	13.1	4.2	2.1	0	2	
	7/30	7	3	13.0	5.5	2.2	1.0	2	
	8/9	7	3	13.5	6.1	2.8	1.5	2	
	8/13	7	3	13.8	6.2	2.6	1.0	2	

Plant Pop.- Planting Date--May 10; Acres--90; Variety--12; Irrigation--Flood; Yield--142

Field Number	Date	Growth Stage	Area of Field	Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
52-101	6/10	2	2	7.7	.1	0	0	0	None
	6/19	3	3	6.4	.15	0	0	0	
	6/27	3	3	6.4	.60	0	0	0	
	7/9	4	3	8.3	2.60	.3	0	1	
	7/15	5	3	14.5	3.90	.8	0	1	
	7/18	5	3	14.4	4.10	.8	0	1	
	7/22	5	3	14.1	7.4	2.1	.8	2	
	7/31	6	3	14.5	9.2	2.4	.1	3	
	8/6	7	3	14.3	9.3	2.3	.1	3	
	8/14	7	3	14.1	11.0	3.7	.5	3	

Plant Pop.- 17,500; Planting Date--April 29; Acres--54.8; Variety--3149, 3395; Irrigation--Flood; Yield--110.3

Field Number	Date	Growth Stage	Area of Field	Average no. of Leaves: Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
52-102	6/10	2	2	8.6	.3	0	0	0	None
	6/19	3	3	6.0	.2	0	0	0	
	6/27	3	3	6.2	.9	0	0	0	
	7/9	3	3	8.1	2.9	.2	0	1	
	7/15	5	3	14.6	4.1	.9	0	1	
	7/18	5	3	14.6	4.0	1.0	0	1	
	7/22	5	3	14.3	6.4	2.7	.5	2	
	7/31	6	3	14.5	9.6	2.5	.3	3	
	8/6	7	3	14.5	9.5	2.7	.3	3	
	8/14	7	3	14.0	10.7	3.8	.6	3	

Plant Pop.- 16,000; Planting Date--April 28; Variety--3149; Irrigation--Flood; Yield--128

Field Number	Date	Growth Stage	Area of Field	Average no. of Leaves: Live	In-fested	In-jured	Dead	Area of Plant	Spray Date
52-103	6/10	2	2	6.7	.6	0	0	0	7/24
	6/19	3	3	6.5	.4	0	0	0	
	6/27	3	3	6.8	1.0	0	0	0	
	7/9	5	3	12.2	3.4	.8	0	1	
	7/15	5	3	14.1	6.3	.71	0	2	
	7/18	5	3	14.3	6.6	2.00	0	2	
	7/22	5	3	14.0	7.9	2.7	1.2	2	
	7/31	6	3	13.7	8.7	2.9	1.0	3	
	8/6	7	3	13.7	8.6	2.8	.9	3	
	8/14	8	3	13.5	8.3	3.1	1.0	3	

Plant Pop.- 18.500; Planting Date--May 2; Acres--150; Variety--3369, 3395; Irrigation--Flood; Yield--106

AGRONOMIC FIELD OBSERVATIONS RELATING TO MITE DEVELOPMENT ON CORN IN SOUTHWEST KANSAS

by

JOHN EDWARD RADKE

B. S., Kansas State University, 1965

AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1975

Infestations of three species of mites, Banks grass mite, *Oligonychus pratensis* (Banks); twospotted spider mite, *Tetranychus urticae* Koch; and carmine spider mite, *Tetranychus cinnabarinus* (Boisduval) have been found invading corn fields in Southwest Kansas. Of the three species, *O. pratensis* and *T. urticae* represent the greatest threat to corn growers of the area. Literature review of the mites indicates a past history of infestations at damaging levels to field corn and other agronomic crops. Similarities in biology of the spider mites support adoption of control techniques that will affect all three species.

Physiology of the host plant offers an alternate approach to determining practical control methods. Mite populations appear to be affected by certain plant nutrient combinations, particularly nitrogen and phosphorus, which stimulates carbohydrate buildup in the host plants. Carbohydrate concentration increases as host plant gains maturity which has the potential of encouraging further mite increases. Drought as the result of hot, dry weather enhances the ability of mite populations to desiccate host plants. The cessation of photosynthesis during physiological drought which in turn induces buildup of carbohydrates in the plant and corresponding increases of mite populations was suggested by researchers as the cause of heavy mite concentrations during hot weather.

Agronomic related problems in corn were observed by several investigators. Reduced ear size, stalk breakage and establishment of disease were related to mite feeding on corn plants. Severe mite infestations were present in fields infested with charcoal rot. No final determination was made as to whether mites influenced weak stalk development or were a mode of infestation for other stalk deteriorating organisms.

Field observations on field corn in Haskell County, Kansas, further supported host plant influence on mite populations. The maturity of the corn plant appeared to be the single most limiting physiological factor in the development of spider mite infestations. Increased maturity of the corn generated a corresponding increase in number of mite infested and injured leaves on the plant. Observations further indicated that the spread of mites over the corn plant increased as the host attained physiological maturity.