THE BERMUDAGRASS MITE
ERIOPHYES CYNODONIENSIS (SAYED) (ACARI: ERIOPHYIDAE)
IN FLORIDA WITH REFERENCE TO ITS
INJURY SYMPTOMOLOGY, ECOLOGY, AND INTEGRATED CONTROL

By

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DEDICATION

I dedicate this dissertation
to my wife, Peggy.

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Abstract of Dissertation Presented to the Graduate Council
of the University of Florida in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy

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By

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Chairman: Harvey L. Cromroy
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The Bermudagrass mite, *Eriophyes cynodoniensis* (Sayed), (Acari: Eriophyidae) was first reported as a pest of Bermudagrass *Cynodon dactylon* (L.), in Florida in 1962. This study was concerned with the identification of mite injury and symptomology, understanding the ecology of the organism, and development of control techniques.

Grass injured by this mite generally progresses through the following symptoms: loss of color, leaf twisting and shortening of internodes, formation of "fan" shaped grass caused by extreme internodal shortening, followed by abnormal growth that resulted in cabbagehead-like structures known as a rosette, intensifying of rosetting until individual leaves become short, thick, spike-like growths, and ultimately death of the grass blades and stolons. These symptoms were documented and illustrated.

Several varieties of *C. dactylon* (L.) were studied for inherent resistance to mite injury. It was found under laboratory and field conditions that repeated inoculations with mites failed to produce injurious symptoms or to establish mite infestations on Tifgreen (328) or Tifway (419). Both of these varieties had *C. transvaalensis* Davy in their lineage.

A series of compounds were tested for mite control under field conditions, and aldicarb and phenamiphos gave significant mite control. A similar series of tests with arthropod growth regulators yielded no significant control.

Temperature measurements were recorded in different turf microenvironments on tees, fairways, greens, and roughs on different golf courses in several areas of the State to determine if a preferred temperature existed for mite infestations. Results indicated that *E. cynodoniensis* occurred in large populations between 80° and 111.5°F.

Field observations indicated mites were found to inhabit certain locations on golf courses. If present, mites could be detected in one or more of the following niches; (1) areas where close mowing was not practical such as bunkers, sand trap lips, or along walls of buildings or other structures; (2) along fences: (3) slopes leading to bodies of water; (4) around bases of trees, shrubs, or other plants or obstacles; (5) along margins of the fairways that border roughs; (6) areas where miticides may not be applied due to difficulty in maneuvering spray equipment.

A pest management program of close mowing, utilization of hand sprayers, bare cultivations, and herbicidal treatments helped to destroy the niches preferred by the mites and reduce serious injury.

Mites were found in large numbers in rosettes and were believed to be spread by mowing or scattering these structures by maintenance equipment, golf clientele, wind, and running water.

A modified Tullgren apparatus was used in sampling grass harboring mite infestations from different geographical areas of Florida to determine if predatory mite types could be found in association with the Bermudagrass mite. The most widely distributed predacious mite found was Neocunaxoides andrei (Baker and Hoffman) which may be a great help in reducing mite infestations. Based on the research, a number of suggestions were made regarding an integrated control program for the Bermudagrass mite.

Chairman

INTRODUCTION

Turfgrass differs from most agricultural crops since it is not consumed but is in a constant state of regeneration when properly maintained. There are presently 944,534 acres of maintained turf in the State of Florida (Meyers 1974). Florida has more than 20 million annual visitors, and golf plays an important role in attracting many of these visitors as well as providing a source of year-round recreation and income to the citizens of the state.

Florida leads the nation in new golf course construction averaging approximately 30 new courses per year. Presently there are 640 active courses (Horne, personal communication, 1974). Theoretically, if all the fairways were laid end-to-end, golf could be played around the entire coast line of Florida, up its length and across the panhandle, a total of over 2,000 miles. By 1985, 831 courses are predicted for the state. Golf courses are almost entirely planted to some variety of Bermudagrass. In addition, many home lawns, cemetaries, sod production farms, motels, hotels, parks, airports, and various institutions are partially or totally planted in Bermudagrass.

Maintenance costs for golf courses alone are conservatively estimated at 60 million dollars per year.

According to many workers in the industry, the Bermudagrass mite is the third most important organism, the other two being the weed _Poa annua_ L. and the nematode complex. Evaluating the mite on a more conservative basis, it is still easy to see that it is a major problem and has the potential to become even more severe. The need for this study was brought about by complaints of extensive damage to turf and particularly to golf courses.

The Bermudagrass stunt mite _Eriophyes cynodoniensis_ (Sayed) (Acari : Eriophyidae) was first reported in Florida in 1962, at Patrick Air Force Base, Cocoa (known as the Cape Canaveral Area). It was believed until 1964 to be concentrated on the eastern Florida seacoast but has since been found over the entire state and is active 12 months out of the year in areas approximately south of Palm Beach. The mite occurences appear to be seasonal in the middle and north part of the state with infestations being heaviest in the spring and summer months.

The mite was first found in the U.S. in Arizona in 1959. Soon after this, California, Nevada, New Mexico and Texas reported mites during the 1959-1962 period. Georgia reported the pest in 1962 but it has not as yet become established. Currently, reports have it that the mite has been found in Alabama, but they are unofficial. According to Keifer, the mite is also found in Australia and Rhodesia, with acarologists beliving it to be native to Africa. There has been much speculation as to why the states between Arizona and Florida have not reported any problem with this pest.

Dr. Harvey Cromroy, Acarologist-Entomologist at the University of Florida, and myself were asked to initiate studies that would ultimately lead to some new approaches to control measures of the mite as well as understanding its behavior and ecology.

The organism is considered a true mite but differs from most other mites in that it possesses only two pairs of legs instead of the usual four pairs. It belongs to the family Eriophyidae and consequenlty falls in the category of one of the smallest arthropods known. They are smaller than many nematodes, being only 200 microns in length in the adult stage. The egg is approximately 1/3 the size of the adults and is clear in color with the first nymphal stage being 2/3 the size of adults and more white in color. The adults are worm shaped and a cream to a light-yellow color

LITERATURE REVIEW

General Background

The eriophyid mites (commonly known as gall mites, blister mites, rust mites and bud mites) are the smallest animals bearing an exterior skeleton with which the agriculturist has to contend. They can deform and russet leaves and fruit. They also cause bud blasting and distorted growth of plants, and if allowed to go uncontrolled, frequently cause plant death.

In genreal, there are two types of eriophyids (Keifer 1952); the worm-like soft species known as gall or bud mites, which do all their feeding and breeding under cover; and the rust mites, which are broader, chunkier, often rather flat, with tergites to protect them against the action of light and dessiccation. This latter type feeds and breeds more or less on open-leaf surfaces and, with few exceptions, constitutes the rust mites or leaf vagrants.

The small size of these eriophyids in relation to the quantity of their food host makes possible the development of very large populations. The ability of the individual mites under favorable conditions to hatch, pass through two nymphal stages, and become egg-laying adults in seven to ten days is another reason for dense populations of this arthropod.

Eriophyids to a great extent lack control over their means of distribution and must travel by chance since they depend on wind, insects, birds, and other forms of carriers for their dispersal.

Eriophyids exhibit a very intimate mite-host relationship, characterized by considerable host specificity. Gall formation is another aspect of this intimacy, but the majority of the mites belonging to this family depend on natural botanical formations of their hosts and cause no noticeable injury. They, with few exceptions, remain in locations where feeding and breeding can take place whenever temperatures and conditions permit.

According to Hassan (1928) the cecidologists considered galls and fuzzy spots, now known to be formed by the eriophyid mites, as fungi. Reamur recorded observations of worm-like animals in galls found on leaves of linden trees in 1837 and believed these galls to be caused by these animals and thought them to be the larvae of some small insect.

In 1833, Timpin examined similar linden galls and found mites which were seen by Latreille to be related to the genus Sarcoptes. In 1834, Fee discarded the belief that galls were caused by fungi and advanced the idea of a relationship between mites and galls.

Duges, in 1834, found mites in the galls of leaves of linden and white willow and considered them as larvae. He found eggs in the galls but supposed that the adults laid them and subsequently escaped through the opening of the galls. In 1850, Von Siebold also considered the mites as larvae and suggested that they possibly propagated asexually and the adult form was yet to be found. He gave the name Eriophyes to these mites.

Dujardin, in 1851, examined two forms of galls on linden and willow that had been studied by Duges; found the mites and observed eggs within their abdomens. He concluded that they were adults, contrary to Duges' opinion, and named them Phytoptus.

Scheutin, in 1857, examined blisters on leaves of a pear tree and found mites which he declared to be the larvae of another mite occasionally found on the outside of the leaves. He confirmed Duges' views and argued that what Dujardins thought to be eggs were nutritive organs. Scheutin further described the so-called larvae and regarded the adult as an oval, tender, quick-moving mite found on the larvae leaf surface and proposed the name Typhlodromus belonging to the family (Gamasidae). During the same year (1857), Pagenstecher disagreed with Scheuton's views and insisted that the so-called larvae were truly adults and gave names to several of them and placed them in the genus *Phytoptus*.

Landois, in 1864, studied *Phytoptus vitis* Pgst. and showed the true nature of the mite. He gave a description of its internal anatomy and life history, some of which turned out to be erroneous in some instances.

Many disputes concerning morphology and taxonomy continued among the workers of the period. In America, the true nature of these mites was not known until Shimer, in 1869, recorded the species *Vasates quadripes*.

Walsh, in 1864, working on galls of willow failed to observe the mites and thought the casual agents were cecidomyids. He believed all galls to be caused by gall gnats or sawflies.

Garman, in 1883, was the first in the United States to study the eriophyids more carefully and described several species.

Nalepa began work in 1887 and continued to lead investigations in the study of the eriophyids.

Keifer began his work in the 1930's and has continued to lead the field in the taxonomy of eriophyids up to the present time.

Biology and Ecology

Hassan (1928) did one of the most thorough studies of the eriophyids. His work covered many areas from history to internal morphology in which the biology of the Eriophyes tristriatus (Nal.) was included. Much of the subsequent work of Keifer, Slykhuis, Wilson and many others has been based on Hassan's original study.

Keifer (1938) reported that nearly all eriophyids found in the field were females. He also described Aceria tulipae (K.) and found that the female would lay from 3 to 25 total eggs and did so over a ten day period.

Keifer (1942) reported some eriophyids produced two types of females. He concluded that a female type mite called a protogyne resembled the male and would reproduce shortly after becoming an adult which he referred to as a spring or summer form. The second female type was called a deutogyne and was considered to be the overwintering or vagrant form. The latter type was found to be morphologically unlike the former. In species having the deutogyne forms, the male does not overwinter.

According to acarologists the eriophyids may or may not have both deutogynes and protogynes, and univoltine species may have only deutogynes.

Roivainen (1949) mentioned that eriophyid gall producers had more than one stage. He reported that the two different stages had often been mistaken for two different species. Shevtchenka (1952) reported sexual dimorphism in female Trisetacus keirchisorum N.Sp. as a pest of juniper seeds. The females were characterized by summer and winter forms. This species was found to belong to the oldest genus of eriophyids which was the beginning stage of plant mite parasites.

Shevtchenko (1970) found that in working with the older gall mite *Eriophyes* (Senso strictus) *laevis* (Nalepa, 1891) that the deutogynes were associated with the onset of seasonal phenomena in the host plant caused by a decreasing photoperiod. Hall (1967) reported the following three different systems that occurred in eriophyid life cycles: (1) simple--one type female; (2) complex--protogyne and deutogynes; and (3) unnamed--ovovivparous protogyne. Alam and Wadud (1963) found that sexual demorphism is evident in adults only.

Life Cycle and Habits

There are approximately 1,000 described phytophagous mites belonging to the Eriophyoidea, and although each species appears to be highly adapted to its particular ecological niche there seems to be a great deal of similarity in most life cycles.

Ramsey (1950) reported that most eriophyid life cycles are similar and relatively simple. Krasinskaya (1960) found the apple gall mite went through its entire life cycle in 30 days with the egg stage lasting 10 days. Boczek's (1961) research on eriophyids showed that most gall makers underwent two generations per season. He also reported that in studying the gall mites of Poland that the female mite usually lays one egg per day and most of the overwintering females studied appeared to be fecundated. Boczek compared host plants of 65 eriophyids from Poland and 120 from California and only species of the following genera Oxypleurites, Rhyncaphytoptus, Diptacus and Epitrimerus had similar life cycles.

In Aceria, Phytoptus, Phyllocoptes, and Eriophyes, there are species causing various types of damage and which vary distinctly in development, and some of which are free living. For example, Alam and Wadud (1963) found that the litchi mite, Aceria litchi K., laid eggs singly at the base of hairs constituting the erineum on the leaf surface. Incubation of the eggs took 2.5 days, the protonymph stage lasted 1.5 days, and the deutonymph stage took 6 days including 2 instars. Pre-oviposition time of the female was 1.5 days and adults lived only 2-3 days; therefore the total life cycle was completed in 13-18 days. This is considerably different from other reported life cycles. Baker and Neunzig (1970) worked on the biology of the blueberry bud-mite and reported it took only 15 days to complete the entire life cycle at 19°C. Rosario and Sill (1964) found that the female wheat curl mite, Aceria tulipae (K.), laid from 3 to 25 eggs over a period of 10 days and eggs hatched in 3 to 5 days at 48±5°F, but that little or no hatching occurred at 36±5°F.

Eggs hatched in 2 days at 75±°F. Oldfield et al. (1969) working on *Eriophyes emargenate* K. found it laid 50-60 eggs within the gall caused by the mite.

Sternlicht (1970) reported the citrus bud mite, *Aceria sheldoni* (Ewing), took 12-23 days to go from egg to egg, with 2-14 days usually required for egg hatching at optimum conditions. The average number of eggs laid per female was 6 with a range of 4-8. If females were fed on buds during their larval stage, the egg laying increased to an average of 8 with a range of 5-19.

Environmental Response

Hassan (1928) found that dryness and heat are the main stimulating factors of eriophyids. Dryness will force mites to leave galls and is thus favorable to the distribution of the mite. Summer heat will cause them to be active and.excessive humidity will cause them to be almost motionless. Hassen reported light had little effect but concluded that since the gall formers live inside the structure that they are probably negatively phototropic and become positive as they leave their galls. Hassan reported that the mites are hardy, and *E. tristriatus* can live 10 days at 20°C in a dessicator without food. Costa and Gonclaves (1950) reported that the tomato fungus mite *Aceria cladopnthirus* (Nal.) attacked tomatos more frequently in the dry season, but that the infestation of mites was nevertheless high in the rainy season. Kevorkian (1951) reported the "white mold" disease of tomatoes (which is so-called because of the white erineum produced by the mite) caused by Eriophyes (Aceria) cladophthirus (Nal.) is particularly active at low temperature and high humidity.

Dinther (1951) found only female Eriophyes gracilis Nal. on raspberries at 17-20°C. Jeppsen et al. (1958) found that the citrus bud mite, A. sheldoni, populations increased in warm weather and declined with low relative humidities and/or unusually hot weather.

Rosario (1958) found that high relative humidity in the micro-environment may be the factor in establishing large A. tulipae populations in the field but information of this phenomenon is sparse. Rosario (1964) found that A. tulipae survived without food and water for 30-40 hours at 36±5°F and would live for 3 months in petri dishes at 36±5°F. It was found that these mites survived temperatures of 120°F in the laboratory.

Reed et al. (1964) found that the optimum temperature for laboratory rearing of the citrus rust mite Phyllocopruta oleivora Ashm. was 80°F. It was also found that A. tulipae appeared to need high relative humidity within a rolled wheat leaf in order for the mite species to survive. Sternlicht (1970) reported A. sheldoni egg hatching was most successful at 25°C and 98% R.H., and that hatching was greatly reduced and dwarf larvae emerged at low R.H.'s (35-40%). The minimum threshold for embryonic development was 9°C and for life cycle completions 12.5°C.

Barke et al. (1972) found that the peach silver mite, Aculus cornutus (Banks) K., was active at 22-31°C, while nymphs were active up to 32.5°C but become sluggish at 24°C and inactive at 21°C.

Habitats and Overwintering

It is a common belief among mite workers that many plants would yield an unreported mite species if a worker had time to survey, at the proper time of the year, the numerous plant niches where mites dwell.

Smith and Stafford (1948) found the grape bud mite, Eriophyes vitis (Pgst.), to overwinter under the spur bud and to migrate to the leaf axil of new buds. Putnam (1939) maintained that the plum nursery mites, Phyllocoptes fockeui Nal., and TKT were stimulated to hibernate in various protected plant parts by hardening of the foliage. Dinther (1951) found E. gracilis to pass the winter on and within auxillary buds of raspberries. Stafford and Kido (1952) found the grape bud mite to occur outside the bud on new growth during late April and early May. After the month of May, 98% of the mites were found inside the bud. Kido and Stafford (1955) reported that grape bud mites were found in heaviest numbers in the first 10 basal buds with the seventh having the largest numbers. As the mite prepared to overwinter, it crawled up the canes to the elongate shoots.

Painter and Schesser (1954) found _A. tulipae_ to live in the protected folds of wheat. Wilson (1955) found an undescribed _Eriophyes_ adhering to the bud scales, or and under rudimentary leaves, buds and new growth of plums and peaches. Kantack and Knutson (1958) found _A. tulipae_ living protected deep in the wheat leaf sheaths. May and Webster (1958) reported the grape bud mites was impossible to control at certain times due to its habit of living inside the bud.

Krasinskaya (1960) found that 70-80% of the female apple gall mites, _Eriophyes_ (_Aceria_) _mali_ (Nalepa 1917) Liro 1951, hibernated in the third to fifth bud scale. Morgan and Heldin (1960) found the juniper berry mite, _Trisetacus quadrisetus_ (Thomas), lived within the berry. Boczek (1961) found free living and gall producing mites hibernating in bark crevices and species belonging to the same genus were varied in their overwintering habit. Boczek found deutogynes overwintering in an inactive state that could be interrupted within the laboratory. Protogyne females were found to hibernate more often in the buds.

Shevtchenko (1962) found the alder gall mite, _E. laevis_, deutogyne to be associated with the onset of decreasing photoperiods and the phenomenon it triggered by the mites' host plant.

Talhouk (1963) found _Aceria phloeocoptes_ (Nal.) to overwinter as a fertilized adult female inside almond galls.

Baker and Neunzig (1970) found the blueberry bud mite to have its largest populations in the terminal buds. Early stages were found only in outer basal scales with later stages found throughout the bud. Oldfield (1969) found the prunus finger gall mite, _E. emarginate_ (Nal.), to overwinter as females in old buds situated at the base of the branches. Upon breaking hibernation, the female laid 50-60 eggs within the gall. Zaher and Osman (1971) found _Aceria mangiferae_ Sayed to hide between bud leaf scales of mangos.

Phototaxis

Hassan (1928) assumed that eriophyids were negatively phototropic based on their habits of concealment. Rosario (1958) found indications that _A. tulipae_ was negatively phototropic under laboratory conditions. Hall (1967) found that under certain circumstances other factors counterbalanced eriophyid's response to light, and mites would move to outer leaf surfaces prior to dispersal. Nault and Styer (1969) proposed that _A. tulipae_ was negatively or positively phototactic depending on its physiological state. It was found that the mite was negative under plentiful host tissue and positive if the plant was undergoing tissue destruction.

Taxonomic Status and Descriptions

Three species of eriophyids have been described from Bermudagrass: (1) *Aceria neocynodonis* Keifer (1960); (2) *Aceria cynodoniensis* Sayed (1946); and (3) *Aceria cynodonis* Wilson (1959).

A. cynodonis appears to be a valid species since it has a 7-rayed claw and an obsolete shield design while *A. cynodoniensis* and *A. neocynodonis* have 6-rayed claws and distinct shield lines (Fig. 1). *A. cynodoniensis* was described as having the dorsal setae pointing forward, whereas *A. neocynodonis* had the dorsal setae pointing backward (Fig. 2). In the 1970 publication "Common Names of Insects approved by E.S.A.," the common name for *A. cynodoniensis* was Bermudagrass mite. In 1971, Newkirk and Keifer following the Zoological Code redesignated the type for the genus, *Eriophyes*. This then moved the species *A. cynodoniensis* into the genus *Eriophyes*. In a letter dated December 13, 1973, to Dr. Cromroy, Keifer indicated that the species *neocynodonis* is in synonymy with *cynodoniensis* which he had termed the Bermudagrass node mite. Therefore, the correct scientific name for this mite is *Eriophyes cynodoniensis* (Sayed) and the correct common name is Bermudagrass mite and in neither Bermudagrass Stunt Mite (Cromroy and Johnson, 1972) nor Bermudagrass node mite (Keifer, 1973).

Although Keifer and Newkirk have re-designated the species of the genus *Aceria* into the genus *Eriophyes*, this is not the final taxonomic status. Many acarologists, and in particular the Russians, are dissatisfied with this arrangement since most of the major pest species are in the genus *Aceria* and have had this generic name over the past 15 years. Lindquist (1974) and others are currently appealing to the Zoological Board of Nomenclautre for a ruling on this problem. In addition, there is still some question as to whether the mite Sayed described is synonymous with the mite Keifer described as Keifer has not yet formerly published a synonymy.

There is also confusion about taxons above the generic level (Lindquist, 1974). The current status, therefor, of this species is:

Class Arachnida
- Subclass Acari
  - Order Acariformes
    - Suborder Prostigmata
      - Supercohort Promata
        - Cohort Tetrapodilina
          - Superfamily Eriophyoidea
            - Family Eriophyidae
              - Genus *Eriophyes*
                - Species *cynodoniensis* (Sayed)

Descriptions of the Bermudagrass Mite

To further elaborate on the taxonomic confusion surrounding this species, the original descriptions of Sayed (1946) and Keifer (1960) are presented.

> Original description of: Aceria cynodoniensis new species. Female: 210.9 μ, including capitulum; 43.8 μ broad; colour whitish; cylindrical; rostrum 19.1 μ long with two pairs of setae; dorsal shield somewhat conical with five longitudinal lines and fine sculpture. Dorsal setae 30 μ, projecting forward. Leg I 41 μ, including feather claws (5.4 μ) leg II 40 μ, claw not knobbed. Feather claw 6-rayed, ending distally with a single medium ray. Thoracic setae I 6.5 μ, II 15 μ, III 21 μ; lateral setae 30.5 μ; first ventral setae 36.5 μ; second 6.5 μ third; 2.4 μ; caudal setae 60 μ; genital setae 10 μ; genetalia 24.6 μ long and 12.3 μ broad. Ventral skin structure the last four posterior, sternal divisions with elongated tubercles.
>
> Distribution: The mite is found in lower Egypt and around Cairo. Upper Egypt has not been surveyed. Sayed (1946).
>
> Original description: Aceria neocynodonis, new species Neocynodonis, with a 6-rayed featherclaw (Fig. 1) may be distinguished from other known grass infestors by the clear shield lines (Fig 1) the rounded micro-tubercles (Figs. 1 and 2) set ahead of the rear ring margins, and by the narrow ribs on the genital coverflap.
>
> Female 165 μ - 210 μ long, 40 μ thick, wormlike, whitish-cream color. Rostrum 23 μ long, downcurved (Fig. 3). Shield 36 μ long, 36 μ wide, semicircular anteriorly. Median line in shield design present on posterior 2/3, admedian lines sinuate diverging to rear; two anterior submedian lines, the first sinuate, abruptly curving outward well ahead of dorsal tubercle, a separate line running toward rear of admedian line; second submedian short curving from anterior margin to

about 1/3 on first admedian; line of granulations running to rear margin from second submedian; rear part of shield and sides set with granulations and short dashes. Dorsal tubercles 23 µ apart; dorsal setae 45 µ long. Forelegs 30 µ long; tibia 5 µ long, with seta 8.5 µ long centrally placed; tarsus 6 µ long; claw 8 µ long, tapering, curved down (Fig. 5); feather claw 6-rayed. Hind-legs 26 µ long, tibia 4.5 µ long, tarsus 5 µ long, claw 8.5 µ long, claw 8.5 µ long. Coxae granular, junction line between anterior coxae paralleled by lines of granulations; first coxal tubercles a little ahead of line through third tubercles. Abdomen with about 65 rings, completely microtuberculate, the microtubercles rounded and ahead of rear ring margin. Lateral seta 35 µ long, on ring 7 behind shield, first ventral seta 32 µ long, on about ring 21; second ventral seta 7 µ long, on ring 38, third ventral on about ring 4 from rear 27 µ long. Accessory seta 2.5 µ long. Female genitalia 18 µ wide, 10.5 µ long; coverflap with about 10 narrow longitudinal ribs; seta 8.5 µ long. Type locality: Brawley, Imperial County, California. Collected: June 7, 1960, by Vincent D. Roth, Farm Advisor. Host: <u>Cynodon dactylon</u> (L.) (Graminae-Chlorideae), Bermudagrass. Relation to host: the mites live in the terminal leaf sheaths where they cause stunting, a witches broom effect, and general decline of the grass. Type material: as well as mites in liquid there is a type slide and three paratypes. Additional localities from which this Bermudagrass mite has been received are: California-Westmorland and El centro, coll. by V. E. Roth, June 7, 1970 Westwood, collected June 13, 1969, by F. S. Morishita. Burback, collected June 21, 1969, by Morishita. Arizona--Phoenix, collected September 3, 1959, by J. N. Roney. and submitted by D. M. Tuttle of the Arizona Agricultural Experiment Station. Tucson, collected August 29, 1960, by G. M. Butler (Keifer, 1960).

Galls and Damage

According to Keifer (1952), there are two types of eriophyids; those that feed on the leaf surface like the

Fig. 1. Scanning Electron Microscope Photograph of *Eriophyes cynodoniensis* (Sayed) Showing Rounded Microtubercles (1075X)

Fig. 2. Scanning Electron Microscope Photograph Showing Backward-Projecting Dorsal Setae and Dorsal Shield Lines (2100X)

Fig. 3. Scanning Electron Microscope Photograph Showing Downcurved Rostrum (2100X)

Fig. 4. Scanning Electron Microscope Photograph of Feather Claw Showing Rays (11,500X)

Fig. 5. Scanning Electron Microscope Photograph of Feather Claw (11,500X)

citrus rust mite, *Phyllocoptruta oleivora* (Ashm.), and those that are bud mites and gallmakers. Only the damage caused by the latter type will be discussed.

Galls on plants were first noticed more than 2,000 years ago. Neiswander (1954) reported that gall production was dependent upon stimulation of plant cells in meristematic zones.

Andre (1954) found that many specific names have been given to members in the family *Eriophyidae* solely on the basis of the nature of galls formed by the mite. A gall on a new host often is considered justification for a new specific name even when the mite causing the gall had not been seen.

The majority of the work on new species and subsequent hosts has been done since the early 1950's. There appears to be a constantly growing list of new hosts reported. Many of these host plants are not presently considered economic species. However, the budmites and gallmakers do cause a great deal of damage to plants that are of economic or aesthetic value to man.

Smith and Stafford (1948) reported that *Eriophyes vitis* (Pgst.), the common erineium mite, was associated with stunted cane growth. Kido and Stafford (1955) further reported the extensive damage on grapes caused by *E. vitis* and said the mite was capable of causing severe injury and even death of the plant. Smith and Stafford (1950) reported the following seven basic injury symptoms of grapes caused by mite infestations: (1) short basal internodes; (2) scarification of the bark; (3) flattened canes; (4) zigzagged shaped shoots; (5) dead overwintering buds; (6) barren canes; and (7) witches broom growth of new shoots.

Jeppson and dePietritonelli (1953) were the first to associate abnormalities of lemon fruit and foliage with presence of the citrus bud mite, E. sheldoni, in California in 1947. However, similarly deformed lemons were known in Italy in 1646. Numerous articles have appeared since concerning the damage inflicted on citrus by this mite.

Another eriophyid of economic importance is the blueberry bud mite. Darrow et al. (1944) found that the scales on blueberry buds infested with mites maintained a persistant rosette appearance. Bailey and Bourne (1946) found the feeding by the blueberry mite, Eriophyes vaccinii K., caused buds to be gall-like and often reddened and swollen at the base of the bud scales and on the stems. This mite has created severe problems to the blueberry industry.

A. tulipae was named by Keifer in 1938 when it was found on tulip bulbs. It also attacks onion and garlic bulbs and causes them to dehydrate. The mite moves into the protected leaf folds of these three hosts and causes twisting, curling, stunting, and subsequent yellow mottling. In severe infestations, this species causes permanent disfigurement of plants.

A great deal of research has been done on A. tulipae since it was later proven to vector wheat streak virus, and red streak kernel virus of corn. The mite was given the common name of wheat curl mite. This mite will be discussed under Hosts and Virus Relationship.

Aceria ficus (Cotte) was reported by Ebeling and Prince (1950) as causing an uncommon type of injury to figs. The terminal buds were bleached, and abcission of immature terminal leaves coupled with stunting of growing shoots resulted from mite infestations.

Collingwood and Brock (1959) reported a gall mite, Phytoptus (Eriophyes) ribis Nal., attacked black currants and caused foliage distortion and proliferation of side shoots at the expense of terminal growth. The mite was found to invade the buds and suppress flower development. Phillip (1963) reported Eriophyes (Phytoptus) ribis (Nal.) to cause thick round galls on black currant branches and leaf spots, as well as cortical galls (at the point where the shoot branches from the stems), on several species of plums. Thresh (1963) reported that the malformation on black currants was called "false reversion." E. ribis has caused a great deal of damage on currants (especially in Europe) and a great deal of research has been done there on this mite.

Saksena (1942) reported *Eriophyes prosopidis* (Nal.) caused galls on *Prosopis spicigera* L.

Burkhill (1948) reported witchesbroom on willows as being caused by *Eriophyes triradictus* (Nal.); he also reported that galls had been reported as far back as 1907 and noted that only male trees were attacked.

Eriophyids cause the growth of erinea on many plants. Lamb (1953) found that *Aceria* (Eriophyes) *lycopersici* (Wolfenstern) caused the production of the white hairy patches on stems and leaf stalks. Sheffield (1954) reported excessive "hairiness" on stems and leaves of sweet potato was widespread in parts of Africa. The plants also exhibited stunted growth, thickening of the stem, and auxillary bud death when attacked by a species of *Aceria*.

Numerous eriophyids attack the bud and early flowering stages of plants. Muhle and Konigsmann (1954) found *Aceria carvi* (Nal.) to cause flower deformation in caraway. When the mite attacked the blossom, no fruit was set. The leaves also showed deformations under severe attack. Tripathi (1955) reported that eriophyid mites were the reason for malformation disease of mangos rather than deficiency of mineral nutrients as previously believed.

Snetsinger and Himelack (1957) observed mites to cause witchesbroom of blackberry and reported little work has been done on this phenomenon since 1888. Gibson and

Painter (1957) found A. *tulipae* to cause wheat plants to become weakened and chlorotic. The wheat leaves curl and folded similar to the description of the common witches-broom.

Vereshchagina and Makailyak (1959) reported E. *phloeocoptes* to damage plums via galls. Mature female mites were found to overwinter in galls formed on new growth. The female would be found in numbers of 100-580 per gall and would deposit eggs within the gall. All stages of the mite were found within the gall. Krasinskaya (1960) reported the apple gall mite E. *mali* to cause a normal leaf of 250-280 μ thick to increase to 350-450 μ thick when infested. The mite also caused severe leaf drop.

Agarwal and Kandasami (1959) found that a eriophyid mite caused gall-like blisters on the inner surface of the leaf sheath in sugarcane. Severe injury was confined to the area near the actual infestation and damage could be identified externally by leaf scars.

Kuitert (1962) reported distortion on young cedars caused by *Trisetaeus cupressi* (K.). He found the mite to feed on tissue between the leaf and the stem. Feeding in this area caused distortion under light infestations and the needles became shortened and thickened. Severe infestations caused browning and death. Under mite attack, the internodes did not elongate, terminal growth failed to develop, and young plants became "bushy" and rounded in shape due to the failure of a "leader" to develop.

Alam and Wadud (1963) found A. litchi attacked young litchi leaves, shoots, and young fruit causing erinea on their surfaces. The leaves were also found to curl, dry up, and drop; and flower buds would fail to develop, and the plant would be stunted. Talhouk (1963) reported similar damage to almonds by A. phloeocoptes. The mite caused irregular galls around buds and prevented fruit formation. Mite infestations reduced vigor of trees so that death occurred within five to six years.

Arnold (1965) reported that eriophyids that originated in flower buds and occasionally on leaves caused galls on Hoheria sexstylosa Colenso. Galls over one year old had well-developed vascular systems radiating from original flower stalks. Colonies of mites and eggs were found in sac-like cavities within the shelter of galls. Arnold (1968) found mites were responsible for transforming flowers into galls on Melicytus ramiflora J. R. and G. Forst. Malformations ranged from callus-like or tumor-like assemblies to leafy clusters resembling witchesbroom.

Stubbs and Meacher (1965) found that a virosis like proliferation (witchesbroom) on lucerne, Medicagi sativa L., was caused by an eriophyid mite, Aceria medicaginis K. The symptoms were similar to those attributed to a leafhopper transmitted virus. A. medicaginis also caused leaf and foliage proliferations in lucerne.

Lavender et al. (1967) found that an eriophyid mite caused Douglas fir trees to have deformed growing tips. Arnold (1970) reported that galls were formed in 6 days on two species of Calystegra sp. after mite infestation. In some galls, there was no leaf tissue present as a result of the powerful morphogenic influence of the gall mite on the shoot apical meristem. This influence, according to Arnold, may depend on the gall mite removing materials from the host cells rather than adding secretory or excretory products.

DiStefano (1971) found that Phyllocoptes triflorae DiStephano formed galls on "Shiro" plums. The cortical galls were formed on twigs. The mite overwintered principally in the adult stage but was also found to do so in the larval and nymphal stages. The galls produced were large enough to contain 350-400 individuals. The mites caused early petal fall, slow growth, and death of lateral twigs.

Kant and Arya (1971) found that gall development on Salvadora persica L. induced by Eriophyes mites was initiated with the laying of eggs. The tissue structure of the gall differed from that of normal leaf tissue particularly in the stomata and mesophyll cells. During the enclosure process, a cup-like structure was formed by the mite. Several cells of inner epidermis along the neighboring cells develop into multinucleate hair cells. The adjoining walls of the cells surrounding the growing hair cells disappeared into the cytoplasma. Nuclear migrations into the body of the hair cell resulted in a multinucleate state. The hair cells also contained numerous starch grains.

Tuttle and Butler (1961) reported that _A. neocynodonis_ caused damage on Bermudagrass in the spring. The grass displayed a typical rosetting and tufting, i.e. a growth caused by a shortening of the internodes and the apparent stimulation of excessive plant growth. Heavy infestations caused the grass to turn brown and die. Eventually, infested lawns became thinned out which allowed weed growth.

Dispersion

Most workers have agreed that one, if not the major, means of dissemination of eriophyids is by wind dispersal.

Pady (1955) capture _A. tulipae_ at a height of 150 feet and for a range of 1.5-2 miles from the nearest population source. This was the first time this species had been found airborne.

Freeman (1946) found mites in insect bodies at altitudes up to 300 feet. Most mites were found at temperatures above 64°F and at relative humidity readings below 60%, with wind speeds below 12 miles per hour. According to Freeman, wind was the most important single factor in dispersion.

Staples and Allington (1956) reported wind alone affects _A. tulipae_ dispersal and temperature was not important. However, the research of Nault and Styers (1969) indicated temperature had a profound effect. Dispersal initiation by mites in tests showed when winds were greater than 15 miles per hour coupled with temperature in excess of 18°C accounted for more than 80% of the number of mites trapped. The researchers further found under laboratory conditions that temperature and light affected dispersal.

Gibson and Painter (1957) found that dispersal was actively initiated by adult behavior since all 10,000 mites captured by them were adults. At the same time, all mite stages were present on the plants and it was concluded that if passive dispersal occurred it would be expected that some immatures would have been trapped. Further study showed that mites were not accidentally dislodged from plants even at wind speeds of 20-30 mph. The researchers found that wind, temperature, and light affected dispersal. An increase in temperature from 12-24°C resulted in an eight-fold increase in numbers trapped. More mites were also trapped in light than in darkness. However, photoperiod effect decreased in magnitude with an increase in temperature.

Slykhuis (1955) and Staples and Allington (1956) mentioned that the eriophyid dispersal by wind was promoted by use of the anal suckers. Gibson and Painter (1957) found that eriophyids apparently control their dispersal by a kind of behavior observed in nearly all species. Eriophyids are capable of holding their bodies perpendicular to the leaf surface and adhering to the plant surface by a pair of anatomical appendages found on and within the anus and called anal suckers. In this perpendicular position, they are likely to be blown from the leaf surface. In addition, A. tulipae will migrate upward and on heavily infested plants will form "swarms of fuzzy appearing masses" of mites on the uppermost tips of leaves. There they will crowd upon one another forming chains of several individuals attached one to another by their anal suckers. These chains break apart from the mite mass and they disperse in a cluster. Gibson and Painter observed that air movement over leaf surfaces stimulates perpendicular standing and chain formation, a factor which could enahnce wind dispersal. It was also observed that only adults move to exposed surfaces on the plant and exhibited "dispersal" behavior except in cases of extreme and rapid plant deterioration when immature forms would also move to outer surfaces.

Hely (1957) found that the citrus bud mite, _A. sheldoni_, may be carried from tree to tree by various insects.

Gibson and Painter (1957) found that aphids moved the wheat curl mite, _A. tulipae_, but that this was of secondary importance. They found that aphids often placed mites into volunteer wheat and other host plants. It was found that the aphids would move into the masses of mites previously mentioned and the mite chains would break and become attached to the aphid. Upon flying away, the aphid then transfers the mites to other plants. The greenbug was the most successful in transporting the mite but the corn leaf, English grain, and apple grain aphids all were found to transport _A. tulipae_.

Butler (1963) mentioned that it could be possible that the Bermudagrass mite, _A. neocynodonis_, could be carried by the wind as well as by insects such as thysonapterons, homopterons, and coleopterans.

Hosts and Virus Relationship

Recent studies have classified approximately 1,000 described species of eriophyids as phytophagous (Whitmoyer, 1972). Liro (1940) found 98 species of eriophyids in Finland. In 1947, Liro reported 178 species and Roivainen

(1947) added another 53 species to the eriophyids of Finland. Roivainen (1950) reported 183 species of gall makers in Sweden. Keifer (1952) reported 186 species from California.

Species of eriophyids that are economically damaging, however, are not restricted to any one geographic region. Hamilton (1949) reported the blackberry mite, *Aceria essigi* (Hassan), to cause the redberry disease in New Zealand. Borgman (1950) reported the same disease and mite as a pest of fruit in Queensland. Lamb (1953a) reported the tomato erineum mite to be found worldwide with the exception of Australia and New Zealand. Zeck (1955) found the dreaded pest of grapes, *E. vitis*, in New South Wales. Connin (1956) found *A. tulipae* able to reproduce on all varieties of wheat, barley, corn, sorghum, Sudan grass, and 12 varieties of wild grasses. This led to examination and discovery of the mite in many previously unreported areas. Wilson (1965) found the pear blister forming mite, *Eriophyes pseudainsidiosis* Wilson, from the Pacific coast of the U.S. to Wisconsin.

Several species of important eriophyids occur in Florida. The citrus rust mite, *P. oleivora*, is presently considered the number one economic arthropod pest of citrus in Florida. Bailey and Bourne (1946) reported the blueberry bud mite, *E. vaccinii*, as a serious pest in N. C. and

Mass, and now Florida has been added (Cromroy and Kuitert, 1973) to the growing list of states where this pest is found. Attiah (1959) reported finding *A. mangiferae* a pest of mango and *A. sheldoni*, the citrus bud mite, in the Miami, Florida area. Within the last few years, the eriophyids have been found to be responsible for more plant damage than just blisters, galls, witchesbroom,and other distorted growths.

Slykhuis (1953) while working with *A. tulipae* as a pest of wheat reported a close association between its feeding and transmission of wheat streak mosiac, a viral disease, and subsequently proved it to be a vector. Painter and Schesser (1954) reported wheat grass as a host of the virus and of *A. tulipae*. Flock and Wallace (1955) proved fig mosiac to be transmitted by the eriophyid *A. ficus* and further showed the disease was not due to toxigenic feeding; Slykhuis (1955) found *A. tulipae* to carry the wheat streak virus in all life stages with the exception of the egg. Wilson (1955) found an undescribed *Eriophyes* and showed it to be a vector of peach mosiac virus. Slykhius (1956) found *A. tulipae* to transmit wheat spot mosiac, a viral disease associated with the wheat streak type. Seth (1963) found an eriophyid mite to transmit a sterility type virus to pigeon peas. Stubbs and Meacher (1965) found a virosis like proliferation (witchesbroom) in lucerne to be caused by A. medicaginis. Williams et al. (1967) found the 3A strain of wheat streak virus to be transmitted to corn by A. tulipae. Nault et al. (1967) found kernel red streak of corn, a virus, to be caused by the wheat curl mite, A. tulipae. Slykhuis et al. (1968) also confirmed A. tulipae as a vector. Proeseler (1968) reported damage caused by gall mites and symptoms of virus to occur together. Whitmoyer et al. (1972) reported eriophyids vector 10 known plant viruses.

Control of Eriophyids

Chemical

The history of chemical control of eriophyids has run the gamut of materials or compounds as has the history of control of other arthropod pests. Keifer (1946), in reviewing the economic eriophyids of North America, stated that sulfur was effective since it blocked the consumption of oxygen by the mite.

Daily and Bourne (1946) obtained control over the blueberry bud mite, E. vaccinii, with the dinitro compounds. Jeppson (1947) found that DDT, dinitrophenol compounds, and di-2-ethylhexyl phthalate controlled the citrus bud mite, A. sheldoni. [illegible]bbing (1947) reported that control of the pear bud mite, Eriophyes pyri Pag., centered around critical timing of spray applications. He found sulfur a better control than the lime-sulfur combination and the wettable type to be the most effective source. Borgman (1950) treated the blackberry pest, E. essigi, successfully with sulfur-mineral oil combinations. Roy and De (1950) found DDT sprays to give good control of Eriophyes species in India.

Kevorkian (1951) found sulfur dust or spray to be a good control of E. cladophthirus, the casual agent of the "white mold" disease of tomatoes in Cuba. Dinther (1952) controlled Eriophyes avellanae (Nal.) and E. gracili with tar-oil plus mineral oil sprays and reported wettable sulfer as well as dusting sulfur to give good control.

Lange (1955) controlled A. tulipae on stored garlic with methyl bromide and sulfur. Zeck (1955) controlled E. vitis on grapes in New Zealand with lime-sulfur. Mansfield (1956) used lime-sulfur to control the citrus bud mite, A. sheldoni, in Australia. Shchegoleva (1958) found lime-sulfur to control E. ribis on currants. Butler and Stroehlein (1965) found it was necessary to use diazinon plus fertilizer to obtain control of the Bermudagrass mite A. neocynodonis, on turf. Either fertilizer or diazinon alone was not significant over controls. Thomas (1960) found chlorpyrifos to control the Bermudagrass mite in nine locations in Florida.

Varma and Yadow (1971) reported the systemics, aldicarb and phorate, to be effective for 75 and 50 days respectively in control of the mango bud mite, A. mangiferae, on mangoes. Bindra and Bakhetia (1971) found demeton-methyl and dicrotophos to control A. mangiferae for 110 days when applied to the trunk of mangoes, but found diazinon and aldicarb ineffective. Dimethoate, phosphamidon, and demeton-methyl which had once shown good control proved less effective in later tests. Sternlicht (1971) found benomyl and mancozeb (two basic fungicides) to control the citrus bud mite, E. sheldoni. Wafa and Osman (1972) found phosalone plus triona oil to give good control when used on A. mangiferae and that acaricide useage statistically decreased the number of stunted buds and malformed inflorescences on mangoes. Bharadivaj and Banerjec (1973) found aluminum phosphide controlled Eriophyes mangiferae (Sayed) on mangoes when shoots and samplings were exposed within a sealed chamber.

Cultural

There appears to be cultural methods that have a great deal of effect not only in controlling eriophyid mites but also in preventing them from reaching population potentials.

Griffiths and Fisher (1949) found copper-zinc-lime sprays to cause an increase in rust mite populations on citrus in Florida. It has become common knowledge among citrus growers that refraining from use of certain sprayable metals and other compounds which leave long term residues on the leaves helps to prevent mite buildup. Barns and McCormack (1951) in preliminary experiments found that the date of pruning effected the severity of injury caused by a physiological strain of the grape erineum mite, E. vitis.

Kuenen (1952) found that submersion of black currant plants in water for 10, 16, or 35 minutes at 45, 43, and 41.5°C, respectively, would control E. ribis, the mite causing "big bud" disease. Slykhuis (1955) reduced A. tulipae populations by destroying infested plants by cultivation, the mites perishing when the plant were destroyed. Hamstead and Gould (1957) found mite populations in apple orchards to be greater in plots of highest leaf nitrogen counts. High nitrogen was found to enable a benign population to become destructive.

Das and Cloudhury (1958) found that thorough pruning of leaves and twigs of eriophyid-affected litchi trees following spraying kept the mites off during flowering and fruiting. Shchegoleva (1958) found that clipping infested buds of the black currant, Ribis nigrum L., helps control the mite E. ribis. He also found pruning of root sprouts on young seedling plus intensive nourishment of the plants aided in control.

Thresh (1964) found that dipping of black currants in water for 40, 30-40, 15-20, and 5 minutes at 40, 42.5, 45, and 47.5°C, respectively, killed all *E. ribis* gall mites without hurting plant growth.

Wafa and Osman (1972) found that pruning old stunted and malformed mango buds, and inflorescence in winter before new buds and inflorescence occurred resulted in decreased *A. mangiferae* populations and prevented migrations to other inflorescence. This operation was considered an acceptable agricultural control method since it decreases infestation levels and gave appreciable yield increases.

Bindra and Bakhetia (1973) also found that pruning of malformed mango twigs and plant parts reduced *A. mangiferae* populations.

Natural

The literature is quite sparse where the effects of natural control agents such as fungi and arthropods on eriophyid populations are concerned. Keifer (1946) mentioned that the eriophyid populations were reduced by predaceous mites, thrips, various species of maggots, and possibly fungi. Painter and Schesser (1954) found thrips, leafhoppers, and the mite *Paratetranychus pratenis* Banks associated with *A. tulipae* on western wheat grass.

Vereshchangina and Mikailyak (1959) reported that Thysanoptera and predaceous mites belonging to the families

Phytoseidae and Anystidae play a significant role in control of *E. phloeoceptes* on plums. Boczek (1961) in studies of the eriophyid mites of Poland found the mites of the family Tydeidae to destroy all stages of the eriophyids.

Gonzalez-Bachini (1964) found that organic insecticides caused death to predators, appreciably in the Erythraeidae, a mite family. It was found that huge differences occurred in the populations of the cotton blister mite, *Eriophyes gossypii*, Banks depending on presence or absence of erythraeids. Alam and Wadud (1963) found predaceous mites to have strong effects on decreasing the populations of the litchi mite, *A. litchi*. Muma (1965) reported that in Florida citrus groves the mites belonging to the genus *Cunaxa* were predaceous and the family Tarsonemidae contained considerable scavenger species.

Baker and Neunzig (1970) while working on the biology of the blueberry budmites found the predaceous mites *Asca citri* Hurlburt, *Typhlodromypis dilbris* (DeLeon), *Cheletogenes berlesci* (Oudemans), and three genera of tydeids: *Tydeus*, *Microtydeus*, and *Triophytydeus*. They also found three species of non-predaceous mites, *Daidalotarsonemus jamebakeri* Smiley, *Tarsonemus summersi* Smiley and *Tarsonemus adamsi* Smiley. The tarsonemids were found to be the most abundant of all the associated organisms. They appeared to be mycophagous in the field and plant tissues injured by the blueberry mite provided necrotic material on which the tarsonemids fed. Baker and Neunzig also found three species of thrips and a cecidomyid larvae that could be predators.

Zaher and Osman (1972) reported predaceous mites did not play a great role in controlling A. mangifera on mangoes probably because the eriophyid pest hides between the bud scales. Alford (1972) found a new species of tarsonemid mite, Tarsonemus aculeus, in association with Eriophyes gallarumtiliae (Turpin) on limes. The tarsonemid utilized the irregular growths structures as a food source and the eriophyids abandoned the galls as their number increased. Bharadivaj and Banerjee (1973) reported that predatory mites of mangoes were killed along with E. mangiferae when the saplings were treated with aluminum phosphide. Spears and Yothers (1924) found an unidentified fungus as a parasite of the citrus rust mite in Florida. Fisher et al. (1949) reported an epizootic of P. oleivora on citrus and suspected a fungus as the casual agent of mite death. Fisher (1950) reported the fungus Hirsutella thompsonii Fisher may be parasitic on the rust mite. Burditt et al. (1962) further described and verified the relationship of H. thompsonii of the citrus rust mite. Leatherdale (1965) reported that several fungal agents attacked the family Eriophyidae. Baker (1968) reported H. thompsonii as a fungal parasite of the blueberry bud mite. He found infected mites to turn greenish-gray, becoming inactive with death following. Hypha were found to extend from the legs, genital, and anal openings as well as from the body wall. Baker found the population of the blueberry budmites and seasonal mortality of bud mites infected with H. thompsonii to show an inverse correlation. The bud mite and the citrus rust mite showed the same symptoms in becoming dark and exhibiting non-natural color when infected with the fungus. High populations of the blueberry bud mite, coupled with increasing rainfall and high temperatures provided suitable conditions for fungus growth. As mite populations and/or rainfall decreased, fungus counts would decrease. McCoy (personal communication, 1974) has developed an experimental control program for citrus rust mite that combined the proper timing of acaricide with fungal outbreaks.

Resistance of Plants to Eriophyids

There has been a limited amount of research dealing with host plant resistance to attack by the eriophyid mites. Philiip (1963) found E. ribis to attack both black and red currants. The mites caused galls in the former but not the latter type. Talhouk (1963) reported a strain of almond in Lebanon that was totally immune from attack by A. phloeocoptes.

Agarwal and Bhatia (1965) found that the genus. Aceria sp., showed a preference for some varieties of sugarcane over others under identical conditions. They also found that in the same variety where the intensity of attack was highest in the eighth leafsheath from the top, the lower sheaths, one through four, were free from attack. Nault and Briones (1968) found on a specific variety of hybrid corn that A. tulipae caused no symptoms without any increase in population;while on a particular inbred line, the mites increased 25 fold in two weeks and the corn reacted severely with leaf spotting, rolling, and trapping.

Sokolov (1967) reported that pear varieties with long shoots, smooth bark without down at the ends, leaves smooth on both sides, and sparse crown appeared to be mite resistant. Plants with tender skin, leaves with thin epidermal layers and with hairy coverings were susceptible.

Bindra and Bakhetia (1969) found numerous mango varieties were infested with the mango bud mite A. mangiferae, but degree of damage varied between and within varieties.

RESEARCH

Bermudagrass Inoculation Tests

Introduction

Several varieties of Bermudagrass were inoculated with *E. cynodoniensis* under laboratory conditions. The information sought in this test was first to obtain information on symptomology and second to determine visably the mite response to the varieties tested.

Materials and Methods

New six inch diameter black plastic pots were filled to within approximately two inches of the lip with soil which had previously been sterilized with methyl bromide. The pots were placed inside the laboratory with controlled temperature which was kept at 85$\pm$8°F. The photoperiod was controlled at 12 hours light.

NoMow, Common, Ormond, St. Lucie, Tifgreen (328), Tiflawn (T-57) and Tifway (419) varieties were tested. The grass samples were obtained from the University of Florida Horticultural Farm Unit. Healthy plots of each grass variety were selected and circular plugs were removed with a standard golf greens cup cutter. The cutter measured 4 1/4 inches in diameter. Each plug contained the grass roots and some soil. This unit measured approximately six inches from the top of the grass to the bottom of the soil and root zone. The prepared excess soil was sliced off the sample just below the area of heavy root development. The grass sample was reduced to approximately four inches by removing the excess soil below the root zone. The samples were labeled as to variety and placed inside polyethylene bags and individually sealed. The bags kept the samples moist until they were planted.

The grass discs were placed in the plastic pots and the soil was added and firmly packed around the disc so that it was level with the top of the grass. This was done in order to promote vertical as well as lateral grass growth. The grass was maintained within the laboratory for six weeks in order for it to overcome the shock of transplantation and become well established. It was watered on a regular basis and fertilized once every four weeks by watering with a plant nutrient solution made by adding 1 level teaspoon of Millers 20-20-20 nutrileaf complete fertilizer per 1000 ml of water. The fertilizer contained the ingredients shown in Appendix A.

At the end of six weeks the pots containing grass that showed poor growth were discarded. The remaining pots were randomized according to variety and marked to become a control or test pot. Each variety to be tested was replicated 10 times. The controls were replicated five times and were kept on a bench at the opposite side of the laboratory and a vaseline barrier was placed between test and control areas.

The inoculum was taken from a known heavy infestation of mites on NoMow variety. Nodules of NoMow were removed and placed within plastic bags. The mites were placed on the potted samples by tearing the infested rosettes apart and placing the parts into the thatch of the grass that was to be inoculated. Two varieties, Tifgreen (328) and Tifway (419), were reinoculated a second time by the same procedure 35 days later.

The varieties were observed daily to determine when the first symptoms of mite injury would be expressed. When the symptoms become evident, a portion of the grass was removed and the presence of mites was ascertained by examining the tissue under a microscope.

Field-established Tifgreen (328) and Tifway (419) were inoculated by the same procedure every week for seven weeks at the University of Florida Horticultural Farm. These supposedly nonsusceptible varieties were the only two tested since the farm has a history of not having known mite infestations. The known susceptible varieties were purposely not tested to avoid the risk of infesting the farm.

The first inoculation was done when the grass reached the standard maintained grass height of approximately 3/8 to 1/2 inch. The subsequent weekly inculations were made as the grass grew taller since the plots were not mowed during the test. This was done to see if the two varieties would show symptomology if allowed to grow. Under normal golf course maintainence, fairways, tees and greens the areas where these two varieties are utilized are kept at a height of less than one inch. In this study susceptible varieties Ormond and common in particular showed little mite damage if kept mowed close. Tifgreen (328) and Tifway (419) which are normally not allowed to grow to a 2-3 inch height (a common height for grass found in golf roughs), were allowed to grow to this height during this test to see if mites would attack (Fig. 7). The test was run on three different occasions according to procedures explained and weekly observations made. Samples were taken of random sprigs of test grass and examined under the microscope. The tests ran for 20 weeks after the first inoculation and nubmerous smaples were observed under the microscope.

Results and Discussion

The first symptoms to occur in the laboratory were on the NoMow variety. This symptom was a shortening of internodes and observed 13 days after the original inoculation was made (Fig. 6). The NoMow variety first exhibited the flat fan type symptom (discussed under Symptomology) and upon microscopic examination revealed that mites were established.

The varieties were observed daily and as the symptoms become evident they were recorded. The data are shown in Table 1.

Table 1. Number of Pots with Grass Showing Bermudagrass Mite Feeding Symptoms after Inoculation with the Mite.

Grass Variety	Days after Inoculation 13	20	27	30	# of Pots of Grass Surviving after 6 months
NoMow	1	4	7	10	9
Ormond	-	1	4	9	4
Common	-	-	2	8	2
St. Lucie	-	1	3	7	6
Tiflawn (T-57)	-	-	3	5	sod webworm damage
Tifgreen (328)	-	-	-	-	10
Tifway (419)	-	-	-	-	10

NoMow was the first variety to begin mite symptoms and all pots in this variety had symptoms to some degree within 34 days of inoculation. This variety continued to hold its color better than did all other varieties including Tifgreen and Tifway. The classic sequence of symptoms were shown by the NoMow variety more strongly than any of the other varieties.

Tiflawn (T-57) and St. Lucie showed symptoms later than did NoMow. It was not known if the mites established themselves as soon as they did on NoMow since microscopic examination was not done until visable symptoms appeared. It is possible the mites were established equally at the same time on all the aforementioned susceptible varieties but that symptoms were not expressed as quickly on some varieties as others due to differing physiological responses.

Another reason for the apparent delay could have been that NoMow developed a closer more compact thatch and did not grow as tall prior to inoculation. The mites from the inoculum could have had a better chance to survive since they were probably in closer contact with the grass in NoMow variety than in the other thinner growing varieties such as Tiflawn (T-57), common, and Ormond.

The symptoms appeared later on other varieties and this could be explained by the fact that all pots were placed side by side and that the original inoculum didn't take on some of the thin grasses variety. As the grasses grew and their foliage touched, the mites could have migrated from one pot to another and thus symptoms could have been delayed due to late arrival of the mite.

It is not known how the mite finds its way to its niche between the leaf sheath and stem. It can be seen from this test that the grass taken from the Horticultural Unit was free of mites since no symptoms were ever seen at field unit and also the fact that none of the pots showed any symptoms during the first six weeks they were in the laboratory prior to inoculation. However, one fact that cannot be overlooked is that later field observations showed that close mowing of susceptible varieties (with exception of NoMow) kept the mites from forming rosettes and thus building up large numbers. Close cut grass expressing no symptoms would occassionally yield low numbers of mites. Therefore, it would have been possible to bring the mites into the laboratory on a disc of short cut grass taken from the field with symptoms that would be expressed some 7-10 weeks later. However, the controls did not show symptoms during this test as they did under a similar replication of this test which will be discussed later in this chapter.

Tifgreen (328) and Tifway (419) did not show any signs of mite infestation in these tests. These varieties were reinoculated a second time in order assure their exposure to the mites. After six months, these two varieties still showed no symptoms of mite infestation.

Even though NoMow had the first symptoms and during the sequence of attack the symptoms were more prominent, the grass in only 1 pot died within 6 months. NoMow variety seemed to be able to live and outgrow symptoms better than did the Ormond, common, and St. Lucie varieties.

Although Table 1 shows the number of pots with surviving grass, it cannot be said that deaths were due strictly to mites since sod webworms got into the laboratory and damaged the Tiflawn (T-57) beyond recovery. The sod webworms also damaged some of the other varieties. At the close of the test period, water was withheld from the pots to see if the mite damaged grass could withstand the stress. The results showed NoMow, Tifgreen (328), and Tifway (419) could stand this condition the best, the latter two of course had not been under any stress caused by mite infestations.

The test was repeated six months later with the following exceptions: (1) only 3 varieties were tested, NoMow, Tifgreen (328), and Tifway (419); (2) the pots were kept in a non-air conditioned greenhouse under normal light conditions; (3) they were replicated 6 times. Tifgreen and Tifway were inoculated weekly for 6 weeks. The results are shown in Table 2.

The NoMow responded the same as it had in the previous laboratory test. All pots of grass were alive at the end of 6 months (Figs. 8 and 9). The control pots were kept

Table 2. Numbers of Pots with Grass Showing Bermudagrass Mite Feeding Symptoms after Inoculation with the Mites.

Grass Variety	Days after Inoculation					
	14	21	28	35	42	49
NoMow	1	6	6	6	6	6
328	-	-	-	-	-	-
419	-	-	-	-	-	-
Control NoMow	-	2	6	6	5	6

on a separate bench. It is not known how the controls became infested. It is possible that due to wind movement through the open greenhouse that the mites were blown to the control pots. A. neocynodonis has been observed during this study to exhibit the perpendicular erection on its body via anal suckers that precedes wind distribution characteristic in the eriophyids.

No symptoms were expressed by Tifgreen (328) or Tifway (419) and no mites were microscopically observed as a result of field testing.

Golf courses were inspected from Jacksonville to Miami, Florida for over two years. Over 200 different greens were examined, samples removed, and microscopically examined; many of them more than once. The greens examined were planted in Tifgreen (328) variety. No *A. neocynodonis* or any damage known to be caused by them were found on any of these greens.

An equal number of fairways were examined and samples handled the same way as the ones collected from the greens. Fairways planted in common, Ormond, and St. Lucie were almost always found to have one or more areas infested with mites during the early spring to late fall. Golf courses in the Ft. Lauderdale area had mites the year round on these varieties.

Only one sample of Tifway (419) ever yielded any Bermudagrass mites. This sample was found on a slope between a tee and a small lake. The grass was approximately 1 1/2 inches in height. The superintendent, Mr. Larry Weber (personal communication, 1973), said the grass was positively Tifway (419), variety. The sample had only a few mites and would have been considered to be an extremely low infestation. Intensive sampling was taken within this area on Tifway (419) and no other samples yielded any mites or showed any internodal shortening. On this golf complex which had 3 separate courses, Tifway (419) variety was used for fairways exclusively and the roughs were planted in common variety. Bermudagrass mites were found constantly in the roughs and damage often was extremely heavy with patches of grass being killed as the result of infestation.

The fairways were kept cut at 1/2 to 3/4 inches in height and the roughs at 1 1/2 to 2 inches. However from time to time the contour mowing patterns would change and roughs of common would be cut short or Tifway (419) (fairways) left unmowed thus serving as a rough.

Even where severe infestations of mites were found on the Common variety, damage stopped with the onset of the Tifway (419) variety. In the aforementioned transition zones where Tifway (419) was found to be 1 1/2 to 2 inches in height, there were no mites or damage observed. Lines of damage were so obvious in these zones of transition that Tifway (419) growth margins could be picked out between the varieties from a distance of 50 feet or more.

Summary

This study showed under laboratory and field conditions that NoMow, common, Ormond, and St. Lucie varieties were highly susceptible to Bermudagrass mite attack and symptoms became evident as early as 13 days after inoculation.

Tifgreen (328) and Tifway (419) were found to be resistant to attack from the mite. These varieties yielded no mites under microscopic examination and exhibited no symptoms from attack by them. This work verified Butler's (1965) that Bermudagrass varieties with parentage of Cynodon *transvaleensis* Davy appears to be resistant to *E. cynodoniensis*. According to Hanson (1965), Tifgreen (328) and Tifway (419) have *C. transvalecnsis* as parentage while St. Lucie, common, and Ormond do not.

Miticide Control Tests--Deerwood

Introduction

The Deerwood golf course, located at Jacksonville, Florida, had a history of Bermudagrass mite infestations particularly on its tees and fairways which were planted in Ormond variety. Greens were planted in Tifgreen (328) variety.

Materials and Methods

The course was inspected in June and Bermudagrass mites were found to infest many areas on the fairways. The infestation was sporadic and dead spots followed a circular or irregular patterns. Certain tees were also infested with mites and one was almost bare of grass. Weeds and non-Bermudagrass varieties were beginning to establish themselves where the original Bermudagrass had been.

The sixteenth fairway was chosen for pesticide tests since it had a history of being the most heavily infested area on the course for mites. Inspection showed

Fig. 6. Beginning of Internodal Shortening of Grass 13 Days after Inoculation under Laboratory Conditions

Fig. 7. Field Plot of Unmowed Grass that Underwent Weekly Inoculations of Bermudagrass Mites


NO-MOW


TIFGREEN

Fig. 8. Pots of Grass Grown in the Laboratory Showing Vertical Growth Seven Weeks after Inoculation

Fig. 9. Pots of Grass Grown in the Laboratory Showing Lateral Growth Seven Weeks after Inoculation


NO-MOW
NOMOW
NOMOW


TIFWAY

mites infesting the fairway which was discolored and had numerous bare spots.

The sixteenth fairway was surveyed and a randomized complete block experimental design was used. Each block was 10 feet wide and 70 feet long and was set to cut across the fairway and through the area of damage as much as possible. The blocks were marked by driving cornerposts of wooden stakes into the thatch so that only 1/4 inch of the stake was above the soil layer. This was done because play on the course was to continue throughout the tests and it was imperative that plots not interfere with golf play or the normal mowing and maintenance operations. The test was replicated four times since adding more blocks would not encompass the damaged grass areas evenly. Each block was divided into seven 10 x 10 ft plots in order to accommodate the six pesticide tests and a control.

The following pesticide formulations and their rates of application were used:

Pesticides*	Formulations	Amount of Formulation Broadcast/Acre
Phenamiphos	15% granular	66.67 lbs.
Aldicarb	10% granular	60.00 lbs.
Trichlorfon + oxy-demeton-methyl	0.375 + 0.125 emulsifiable liquid	21.78 gals.
Disulfoton	15% granular	22.00 lbs.
Fensulfothion	15% granular	66.67 lbs.
Propoxur	70% wettable powder	11.00 lbs.

*further information available in Appendix D

The rates of application for each pesticide were selected as the most likely amount the Environmental Protection Agency (EPA) would register for future use on turf.

The pesticides to be used on individual plots were measured and weighed in the laboratory prior to application. They were placed in glass containers, labeled, and sealed. The granulated materials were placed inside a glass jar with a lid perforated by nail holes. This allowed the granules to be shaken out evenly over the plot. The holes in the lids on the shakers were designed prior to actual application so that the flow of the granules would not be too rapid. Several size lid holes were used since the various granules were of different size and texture and the flow rate varied In order to insure uniform spread of granules, each plot was covered using a broadcast pattern from 4 to 6 times with the shaker or until the specific amount of granular material had been applied as evenly as possible. The standard procedure was to start on one corner of the plot and go from that point to the opposite side and then return. This continued until the plot had been crossed from either a north to south or south to north pattern. The procedure then consisted of an east to west or west to east movement. The procedure then rotated back to the north-south; then to east-west pattern until the supply of granules were distributed.

The premeasured and weighed liquid and wettable powder pesticides were carefully emptied into a 2 1/2 gallon garden sprinkler can from their respective glass containers. The container was then rinsed several times into the sprinkling can to insure that all of the chemicals was used. Water was then added until the can contained approximately 2 gallons of the finished mix. This amount was equivalent to approximately 880 gallons per acre which is more than is applied to most golf courses in normal spray application. However with the sprinkler can delivery system, this amount was thought to be necessary in order to reduce the error in application.

In order to insure a good mix of water and materials, the contents of the can were stirred vigorously with a clean wooden paint stirring paddle.

Liquids were applied with the same criss-cross procedure as on the granular application plots. The cans were rinsed several times before adding the material for a new plot. To reduce chances of contamination, a different sprinkling can was used to apply each pesticide.

Approximately 4 hours after the application of all chemicals, the irrigation system was turned on and 1/4 inch of water applied to the test area. Another 1/4 inch of water was applied at dawn on the following morning. This was one to wash off any remaining residue of toxic materials and to wash in the granulated materials. The addition of water was also used as a safety factor for the golfers who would be playing the following day. The reason for the four hour lapse period between application and irrigation was that Deerwood closes play every Monday for maintenance and this was when the treatments were applied.

After the applications, the sixteenth fairway was treated the same as was the rest of the course grass and was kept cut at standard fairway length of approximately 3/4 inch. The plot ratings were based on Butler's (1963) procedures where overall grass growth, color, and general vigor of a plot was scaled from 0 to 10, with zero being bare soil and 10 being a perfect plot showing no damage. In order to reduce error, the ratings were made by two individuals and the results averaged. Cooperators were Drs. H. L. Cromroy and David Bowers. Rating observations of each plot were confined, as much as possible, to the six by six foot middle section. This allowed a two foot border of grass in each plot and helped reduce human bias. The grass plots were rated on the day of pesticide application to establish a beginning reference baseline and ratings were made every 14 days thereafter for 6 weeks.

<u>Results and Discussion</u>

The results of the test are presented in Table 3. Statistical analysis using Dunnett's Test (Cornell, personal

Table 3. Visual Rating with Six Pesticides at Deerwood Golf Course.

Treatment**	Pre-application*	Days after Treatment 14	28	42	Net Change in Rating after Treatment
Phenamiphos	6.125	7.000	7.125	7.250	(+)1.125
Aldicarb	5.125	5.625	6.825	6.825	(+)1.700
Trichlorfon + oxydemeton-methyl	3.125	3.500	4.500	3.875	(+)0.750
Disulfoton	7.375	8.125	6.625	6.500	(-)0.875
Fensulfothion	6.125	6.875	6.750	6.625	(+)0.500
Propoxur	7.625	7.875	7.125	6.625	(-)1.000
Control	6.750	7.000	7.250	7.000	(+)0.250

* Each plot is the average result of combining two ratings on four plots

**For further information on pesticides, see Appendix D

communication, 1975) showed that plots treated with aldicarb were significantly better in appearance at the 0.05 level than the controls during the range of time the test was run. Aldicarb plots were not however significantly better in appearance than plots treated with phenamiphos, fensulfothion, or trichlorfon+oxydemeton-methyl. Plots treated with these four materials were significantly better at the 0.05 level than those treated with disulfoton or propoxur. The turf treated with the latter two materials regressed in appearance but regression was not significant when compared to the control. It is not known why regression occurred since variables too numerous to list could have been the reason. However, there is a possibility that the chemicals could have had an effect on beneficial turf arthropod complexes.

Although a great deal of information was obtained from this test, a follow-up or continuation would not be recommended because of the following problems and criticisms.

Although this was the most realistic field research, it is difficult to work in the main area of traffic on a golf course. Setting up plots in the flow of play constantly creates problems between golfers and researchers. Another problem encountered was the marking of plot layout so that it can always be found days or weeks later. The marking was difficult and remeasurement must be precise in order to re-establish block corners or other orientation points. This procedure must be repeated each time the plots are rated or observed. In a case where fairways, tees, greens, or other playable areas are utilized, it is imperative to use markers that do not project more than 1/4 inch above the soil surface. If stakes or other devices are used and this height is exceeded, mowing and other maintenance equipment will often destroy the markers and will become damaged themselves in the processes.

Another criticism for not using these areas for testing was the mowing process. It was later learned that mowing hinders the normal population development of the Bermudagrass mite. Thus, as a test was developing with mowing being mandatory, the rosettes, fans, or other nodular growth portions which harbor the majority of the mite population was cut, mulched, and scattered over a wide area. Counts taken after these operations could be misleading as to the actual control that was being obtained by a pesticide at a given time.

The most severe criticism is in the area of plot layout and sampling technique. A plot layout that contains a relatively uniform mite population is mandatory. It should be pointed out that at the time this test was initiated little was known of the mite population or their habits. Therefore the large 10 x 70 ft blocks were adopted. Populations were never found to exist uniformly in areas this large over the 2 1/2 year period covered by this study. Extreme populations of mites were found in later observations but many times their damage was confined to small isolated spots.

Summary

Ormond Bermudagrass infested with A. cynodoniensis (Sayed) was treated with six different pesticides. Ratings of control consisted of a visual classification technique where plots were scored from 0 (no grass) to 10 (perfect) grass.

The plots were rated at 14, 28, and 42 days after treatment. Plots treated with 60 lbs. of 10% aldicarb granules were significant over the controls in appearance at the 0.05 level.

Miticide Control Tests--Palmaire

Introduction

Palmaire is a golf and condominium complex located at Pompano Beach, Florida, and consists of four par 72 professional type 18 hole golf courses that lie among a vast layout of living facilities. The fairways are planted in Ormond variety Bermudagrass and complaints of mite attack on them had been numerous.

Materials and Methods

The four courses were thoroughly inspected in order to establish an area that was uniform as possible in mite infestation and large enough to accommodate sufficient plots to test several pesticides. The courses had spots of mite outbreak on numerous fairways and roughs. A great majority of the infested areas were too small for the plot area required to run pesticide tests.

A general infestation followed the slopes along a stream that meandered through the Palmaire courses; but due to slope and sparseness of grass, it was decided not to select a test area along the stream.

A randomized complete block design was set up in the areas that contained the largest and most even population of mites found in the preliminary survey. This area also had a history of having constant mite problems. The blocks were replicated three times and the treatments were five by five feet in size.

The original plans were to replicate the test a minimum of four times and for the treatment plots to contain 100 square feet rather than 25. However, the overall infestation was not sufficient for a test of this size so less replication and smaller areas of treatment were made. Two blocks five feet wide and 50 feet long were laid out and corner stakes used for markers the same as was discussed under Deerwood Control Tests. Due to the irregularity of the mite infestation, the third block had to be made L shaped. The plots that were to be tested had a reasonable equal growth of grass and about the same topography with little or no slope. In order to be able to find the plots more easily a small amount of herbicide was used to kill the grass, in a circle approximately two inches in diameter surrounding the corner stakes.

The herbicide was also used on the corners of each 5 x 5 ft plot. This allowed for future sampling without having to re-establish block and plot boundaries. This herbicidal procedure was used in this test since the infested area was located between the rough and the tee and the dead spots were not detrimental to the appearance of the course. This procedure also eliminated the excessive use of stakes used in relocating plots. Palmaire management had requested that no test was to be visible to the clientele, and mowing maintenance had to continue during the testing period.

The following nine materials, rates per acre, and formulations were used;

Common Name	Formulation	Amount of Formulation Broadcast/Acre
Aldicarb	10% granules	60 lbs.
Phenamiphos	15% granules	66.67 lbs.
Fensulfothion	15% granules	66.67 lbs.
Disulfoton	15% granules	22.00 lbs.
Diazinon	4 emulsifiable liquid	1.00 gal.
Dialifor	4 emulsifiable liquid	1 qt.
Trichlorfon oxy-demetonmethyl	0.375 + 0.125 emulsifiable liquid	21.78 gals.
Oxamyl	2 emulsifiable liquid	1 gal.
Fentine Hydroxide	50% wettable powder	1/2 lb.

The materials used were previously weighed under laboratory conditions, placed in glass containers and properly labeled.

The application of granules, wettable powders and emulsifiable materials were done as described in the Deerwood Tests. The weather was usually windy in the Pompano Beach areas. In order to avoid granules or liquids from being blown away, the applications were made to the plots from a height of approximately 1 to 1 1/2 feet. Application was made only when there was either no wind or a very slight breeze. If wind speed increased beyond a very soft breeze or if there was any indication that the wind was causing granules or liquids to be blown away from the plots, treatments were stopped until permissable conditions occurred. Fentine hydroxide and oxamyl were not available from the manufacturers at the time of treatment. They were applied 14 days after the other materials. The statistical analysis was designed in order to consider this alteration and will be discussed further under Results.

Sampling. Grass samples were taken from the test plots 2 and 4 weeks after the application of pesticides. According to Reinert (personal communication, 1973), counts taken sooner than 14 days could be misleading since deterioration of dead mite bodies appeared to be slow and could be deceptive if readings were taken prematurely.

Before sampling, care was taken to re-establish all plot boundaries. The sample was taken from the center of each plot. This allowed approximately a 1 1/2 to 2 foot buffer zone in each plot. Since plots were not separated by nontreated boundaries, samples taken from any two adjoining plots were a minimum of 3-4 feet apart. The sample consisted of approximately 500 cc of individual rosettes, fans, or other damaged appearing grass. The samples were placed in a plastic bag, sealed, and put in a shaded area. As soon as all samples were collected, they were held for microscopic examination in air-conditioned rooms where the temperature was maintained at 68°-75°F.

The Bias Sample. The bias sample technique was developed by necessity and can be explained by data in Table 4. An attempt was made to sample known mite infested areas on Palmaire courses. The technique used was to randomly remove an approximate 10-20 gram portion of grass within an infested plot. These samples usually did not contain any rosettes, fans, or other symptomology indicative of mite damage. When actual microscopic counts of these samples were made, mites were found in insufficient numbers to work with. When a random sample contained a rosette the numbers of mites found and compared it with a random sample where rosettes did not occur were so extreme that the over balance discouraged even the remotest conclusion.

Table 4. Comparisons of Mite Counts from Random Grass Samples and Biased Samples.

	Total Numbers of Mites	
Sample No.	Random Sample*	Biased Sample*
A1	5	935
B2	4	323
C3	2	290
D4	8	725
E5	2	704
F6	3	78
G7	9	565
H8	3	226
I9	2	347

*Each sample is composed of the average of 5 subsamples

From this experience, it was decided that samples would be used from both treated and control plots made up of grass portions (rosettes, etc.) which contained abnormal growth caused by the mites. It was felt that a better comparison could made using this sampling technique. The bias sample is in need of modification because this method also yielded large differences in populations even when it was highly suspected that none exists. This error could probably be reduced by extracting mites from larger numbers of samples from a larger area. Time was not available for the person doing the counts to increase the number of samples.

Counts. Actual counts wyre usually made within 18-24 hours after sampling. It would take about 48 hours to examine the samples. As much as 72 hours often elapsed from the actual time the sample was taken and subsequent counts made. In order to reduce any bias, the plot samples were examined on a random basis.

A subcount was begun by taking the sheaths at random from a mite infested rosette with a pair of jewelers forceps. The sheaths were then carefully placed inside up and all stages counted except egg. A subcount consisted of the total mites found under a 16 X lensfield of an A. O. Spencer dissecting microscope.

In order to reduce error, five rosettes were randomly selected from the composite sample and a separate subcount made on the sheaths as previously explained. The final total count of a recorded sample was composed of the average number of mites found in the five subcounts.

In order to obtain useful and working data, it was decided to use the bias method of sampling. A comparison of the two methods of sampling is given in Table 4. It was found that a total of only 94 mites were found in 125 random type grass samples compared with a total of 7,528 mites found in 110 bias type samples.

Data is presented in Table 5 concerning the miticide tests.

Table 5. Mite Counts Resulting from Application of Pesticides at Palmaire Golf Course

	Days after Treatment					
	14			28		
Treatment	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
Control (A)	226	565	41	220	30	5
Aldicarb	79	3	41	0	0	0
Dialifor	2	204	5	160	43	1025
Diazinon	2	347	140	0	0	0
Trichlorfon + oxydemeton-methyl	249	34	290	460	795	473
Phenamiphos	323	4	277	0	0	300
Disulfoton	36	303	725	385	30	0
Fensulfothion	935	856	486	0	5	1280
Oxamyl	85	255	490	12	160	120
Fentine Hydroxide	925	425	174	848	512	325
Control (B)	760	795	420	536	915	286

Results and Discussion

It was decided after discussion with an IFAS statistician to combine the data obtained from not only the two periods of sampling but to also combine the data from the oxamyl and fentine hydroxide treatments, since separate controls were added to the test to compensate for delay of application of these two materials. The data were examined and analyzed by acceptable statistical techniques so that all treatments could be compared to the control and all treatments could be compared with one another. Tables showing statistical methods and calculation are shown in Appendix C.

Standard A. O. V. Tables indicated that significance existed when the sampling data was transposed using the log (1 + y) or $\sqrt{1 + y}$. These tables are presented in Appendix C. This transportation was necessary since the range between samples were so large.

Dunnett's test showed aldicarb, diazinon, and phenamiphos to be significant over the controls at the 0.05 level.

Duncan's multiple range test was used in order to compare significance to treatments with each other and the results are presented in the following table:

Table 6. Overall Results of Bermudagrass Mite Control; a Statistical Comparison Using Duncan's Multiple Range Test.

Pesticide	Level of Comparison*
Aldicarb	a
Diazinon	ab
Phenamiphos	abc
Dialifor	bcd
Disulfoton	bcd
Oxamyl	cd
Fensulfothion	cd
Trichlorfon + oxydemeton-methyl	d
Fentine Hydroxide	d

*Pesticides followed by the same letter were not significantly different at the 0.05 level.

Summary

It was found that aldicarb, diazinon and phenamiphos had significanlty fewer Bermudagrass mites than controls 28 days after application. There was no significant difference between the miticides when compared with each other.

Growth Regulators Tests

Introduction

The Inverrary golf and condominium complex, located at Lauderhill, Florida, is composed of two professional par 72 and one par 60 executive courses. The tees and fairways are planted in Tifway (419) and the greens in Tifgreen (328). The roughs are planted in common Bermudagrass and landscaped with subtropical type plants and trees. The roughs are delineated from the fairway strictly by mowing. Fairways are kept cut at 5/8 to 3/4 inch in height and the roughs at approximately 1 1/2 to 2 inches. Changes in mowing patterns will occasionally produce the margins of the rough with Tifway (419) and the fairways with common variety. The course management reported sporadic outbreaks of mites on the complex and complained that mites could be found the entire year.

Materials and Methods

The entire turf complex was thoroughly surveyed. Mites were found in isolated spots along the roughs or where common variety was found. The infested areas were too small and isolated to attempt to try and set up a statistically acceptable pesticide test.

The course was kept under surveillance for almost a year. During the spring of 1974 an area along the rough of "number 2" fairway on the West Course was found to be infested with mites. The infestation extended for approximately 100 feet in length and from 15-20 feet wide. The area was intensely surveyed and although infestations were sufficient to support a test there were breaks within the area that had few mites and little damage.

The Bermudagrass in this area was approximately 1 1/2 inches in height. The entire area was flat and moisture conditions were considered to be somewhat minimal. The fertility program in this area was considered to be excellent.

Previous correspondence with Zoecon Corporation of Palo Alto, California had led to the investigation of using several growth regulators in attempting to control the Bermudagrass mite. Zoecon had reported that six numbered compounds had shown miticidal and ovicidal activity against the two spotted, the European red and the brown almond mite. The materials were recommended as foliar treatments and supposedly showed no systemic action. All materials were 25% wettable powder formulations and were to be applied as a 0.1% finished spray.

The area to be tested was examined and seven sub areas that appeared to show equal symptoms, grass color and growth characteristics were selected. The seven plots were randomized as to what treatment they would receive. A 10 x 10 ft aluminum pipe template was made and each side was marked at the halfway point so when it was laid flat on the turf a 100 square feet section was marked off. This area within the template could then be divided into 4 subsections by lining up the midpoints marked on the sides of the template. Each of the four five by five sections within the template was to serve as a replication of the same treatment.

The area within the template was delineated by using an inverted spray paint golf course marking apparatus containing magenta colored paint. This apparatus is commonly used to make boundaries on golf courses during tournament play.

The growth regulators to be used were weighed out prior to testing and placed in glass containers. The weight of the test material was precalculated so that when mixed with a quart of water it would yield a 0.1% spray.

A container was premarked so that when it was so filled it contained a quart of water. This amount was selected to be used since most spray machines on golf courses apply approximately 100 gallons of water per acre in spraying for disease or mites. One quart of finished spray per 100 square feet is equivalent to 108.9 gallons per acre.

The materials used were as follows:

Material	Form	Rate AI/A	Lbs. Formulation/A
ZR 793	25% WP	.908705 lbs.	3.6351 lbs.
ZR 856	25% WP	.908705 lbs.	3.6351 lbs.
ZR 918	25% WP	.908705 lbs.	3.6351 lbs.
ZR 1829	25% WP	.908705 lbs.	3.6351 lbs.
ZR 1859	25% WP	.908705 lbs.	3.6351 lbs.
ZR 1888	25% WP	.908705 lbs.	3.6351 lbs.

Mite precounts were made prior to applying the growth regulators. The bias system of sampling was used. Since the material applied was considered to be an ovicide, a ratio of all stages of mites to eggs were established. A sheet of paper with a small rectangle was constructed and a section of the infested leaf was placed on the rectangle. Observations were made at 45 X power using an A.O Spencer dissecting microscope and the mite eggs were counted and compared with the nymphs and adults found within the confines of the rectangle. Results of the count ratios shown in Table 8.

Two applications of the growth regulators were made, the second 18 days after the first. The material was applied to each 100 square feet areas by using a 1 1/2 gallon compressed air sprayers. The wettable powder hormone was added to the tank from the glass container. The containers were then rinsed using water from the premeasured quart that was to be applied to each 100 square feet plot and the rinse water added to the sprayer. When the glass container no longer showed any visible residue from the wettable powder, the rinsing operation was stopped and the remainder of the quart of water was added to the tank. The tank was closed and the spray mixture was shaken vigorously to aid mixing.

A different, clean compressed air sprayer was used to spray each individual material. The procedure for spraying each block followed the pattern as described under the Deerwood tests. The compressed air sprayer was chosen for this test because it would deliver small amounts of spray more evenly than the sprinkling can method. In order to reduce spray drift the sprayers were operated at low pressure so that droplet size was too large to be blown away by slight air movement. Using this procedure it took from 8 to 10 "times over" the plot before the spray was exhausted.

Counts were made on April 18 using the system previously described on May 6 just prior to the second application and then on May 30 as a follow up to the second treatment with the results shown in Table 7.

Table 7. Mite Counts in Total Numbers at the End of 18 and 42 Days after Treatment, Ineverrary Golf Course

Treatment	Block I 18	I 42	II 18	II 42	III 18	III 42	IV 18	IV 42	level of comparison*
ZR 793	496	577	716	432	1080	756	1350	703	ab
ZR 856	592	399	980	137	640	417	1200	960	a
ZR 918	556	1082	380	1344	708	1062	580	1080	c
ZR 1829	336	565	140	784	1500	530	1280	552	ab
ZR 1859	800	744	384	404	460	624	1070	1338	a
ZR 1888	480	420	884	376	732	274	743	768	a
Control	476	628	290	710	700	555	555	600	ab

*Dunnett's test at 0.05 level

There appeared to be no significant changes in mite population during the test.

Results and Discussion

No significant differences were observed between any treatments at the end of 18 days. Significance was obtained between treatments at the .01% level at the end of 42 days using the standard A.O.V. table. Dunnett's test was applied to the data and it was found that the reason for significance lay in the fact that the growth regulator ZR-918 had tremendously high mite populations when compared to the other compounds and the control. There was no significant difference between the other compounds when compared to the control at the .05 level. Compound ZR 856 and ZR 1888 however did prove significantly better than compounds ZR 1859 and ZR 918 at the .05 level. A.O.V. tables and Dunnett's test are included in Appendix D.

The results of the adult plus nymphs to egg ratio are presented in the following table.

Table 8. Ratio of Nymphs Plus Adults to Eggs at 18 and 42 Days after Treatments

	Treatment							
Days	Control	ZR 793	ZR 856	ZR 918	ZR 1829	ZR1859	ZR 1888	Totals (T)
18	1:4.591	1:2.649	1:5.296	1:3.195	1:1.365	1:5.857	1:2.857	25.81
42	1:0.385	1:0.673	1:0.783	1:0.419	1:0.418	1:0.983	1:0.415	4.076
							Total	29.886

@ 18 days $\bar{E} = 3.687$ $\chi^2 = 4.21$
@ 42 days $\bar{E} = 0.582$ $\chi^2 = 0.541$

It was found and can be supported by the above data that the variation in the adult + nymph : e ratios ranged from 3 to over 11 fold.

However the chi-square values in comparing the treatment and control ratios with each other at the 18-day interval and with each other at the 42 day interval showed that the variations that existed were not significant.

The reason for the sharp drop in ratios is unexplained and could be due to many known and unknown environmental factors.

It is possible that predatory mite forms could have been the reason for part or all of the ratio changes, since it is known that some of the mites found during this research are predaceous on mite eggs.

<u>Summary</u>

No positive significance was found between six growth regulators and the control when tested against the Bermudagrass mite infesting common variety Bermudagrass.

The materials were also being tested for ovicidal properties and no significance was found between the compounds and the control.

Symptomology

The first symptom of the Bermudagrass mite feedings is not always easy to detect. The patterns are not always the same and the sequence of injury that can lead to grass death appears to vary from one plot to another. This observation is not unexpected and can partially be explained by the fact that management programs of grass differ widely from golf course to golf course.

There is a general pattern of attack by the mites and subsequent symptoms do follow a sequence. The first stage is a slight yellowing (particularly in Ormond and Common varieties) of the very tips of the blades of grass on which the mites are feeding. The yellowing can be more or less pronounced and probably depends upon variables such as fertility, moisture and other associated factors in a turf complex. No Mow variety does not exhibit the pronounced yellowing characteristic as do the previously mentioned varieties.

The second stage is characterized by twisting of the leaves and shortening of the internodes especially under moisture stress. The leaf twisting alone is commonly referred to incorrectly by many lay observers as "witchbrooming." Leaf twisting is expressed by the fact that the margins of the leaf role upward and inward and thus each individual leaflet appears in a tight rolled position (Fig. 10). A plot of grass if observed as an entity takes on a darker appearance which begins at the tip of the blade and proceeds back to the point of its insertion at the node. As this condition progresses from leaf to leaf then that particular sprig of grass takes on a thin spindly appearance. This phenomenon is a condition of wilt and has probably been termed "witchbroom" because the blades actually look "stringy" as would the tips of a worn-out broom. This condition is only a response by the grass to reduce the loss of water when it is under moisture stress or comes about when conditions exist where water is in a short supply. Many times it was observed that the leaf twisting never appeared in mite-infested Bermudagrass which was heavily watered.

As this study began it seemed to be the opinion of many turf workers that when they observed "witchbrooming" (leaf twisting) during the season for mites, especially when they had been reported in the area, then the diagnosis was commonly made as mites. Often mites were the reason but this overall observation proved to be very misleading.

Literally hundreds of these witchbroomed areas were observed and taken apart. Samples were brought into the laboratory and each sheath stripped and observed under the microscope. An occasional mite was found and a small colony would also be observed from time to time. However a great majority of the time mites were not found. When the leaf twisting did occur the pattern would be found as irregular spots from a few inches in diameter to one that would cover several hundred feet. This pattern did resemble one that would occur when a pest organism establishes a population in turf, however thinking that the numerous leaf twisted spots meant mite infestations proved to be wrong. Many environmental stresses were found to cause the described condition in one instance or another and many times an answer didn't appear to be available. Often observation led to the fact that nematodes were the culprits and the grass responded quickly to nematicide treatments. Root disease and damage often were the reasons for the symptoms. The aforementioned reasons were many times associated with the leaf twisting even though the overall moisture conditions of a golf course were considered adequate or even good, and this often would further lead the casual observer to think that a heavy infestation of mites was present.

During this study it was found that several varieties of grasses other than Bermudagrass would show the leaf twisting symptoms. All Bermudagrass varieties did appear to show the symptoms far earlier than did other grasses.

Further investigations often resulted in finding irregularities of the top soil on which the grass was established. Many golf courses have top soil hauled in to provide a media for the vigorous crop of grass desired. In spite of all efforts, often a spot of rock or sand pocket would exist and be devoid of any of the top soil or organic matter which is a good moisture retaining agent. The result of this action would cause the grass to wilt within this given spot and subsequently mites would be blamed. These sand or rock pockets help explain the fact that in spite of the addition of several inches of water the leaf twisted areas can appear within a few hours after cessation of watering. This condition was brought about by the high temperature and subsequent transpiration rates of Bermudagrass coupled with the poor water holding capacity of the sandy soil or other poor growing media in these troubled spots.

The Bermudagrass mite was only occasionally found associated within the spots containing the leaf twisting. When mites were found, leaf twisting was coupled with shortening of internodes observed (Fig. 11). If the nodules and rosettes (which will be discussed further in this section) caused by the mites were present, then they would be more likely to be seen and would draw the attention of the observer to the infestation. A thick rosette anywhere from 1/2 to 1 inch in diameter is likely to stand out within the wilted grass area. At times these rosettes would be numerous and it was considered that these "cabbage head" appearing clumps had been in existence for quite some time in order to be as far advanced in their development as they were. It is felt that the wilted condition allowed the rosette to be observed so the mite was often blamed as the culprit for the overall wilting.

The third step in the sequence (if "leaftwisting" can be considered the second) is what is termed true witch-brooming. This condition results from a shortening of the internodes on a normal grass stem until there are many individual blades growing close together and appearing to radiate from a common point. In its early stage, the leaf particularly in No Mow variety begins to take on the appearance of a flat fan (Figs. 13, 14, and 21). This flat fan is not usually as pronounced in Common, Ormond, Tiflawn (T-57), or St. Lucie varieties but does exist. Witchbrooming will exist in various degrees of intensity within a mite-infested area.

The fourth symptom is what is termed the primary stage of the rosette. When this occurs, numerous leaves or leaflets appear to have their basal insertion at one point. This stage loses the flat appearance and takes on a round "clump like" appearance. The grass no longer appears to possess any internodes, the leaves are so numerous that several dozen will be arranged in a whorl and will touch one another (Fig. 15). The fifth symptom can be considered the secondary rosette. The individual grass blades lose their sharp edges and become semi-oval and spike-like in appearance. They are a great deal shorter and stubbier than normal leaves. This total leaf distortion coupled with the condition where leaves are so numerous and compact converts the grass spikelet into a cabbage-head appearing body. The rosette then continues to enlarge and may reach the size of 1 1/2 to 2 inches in diameter and 2 inches or more in height (Fig. 16). The roseiting may become tighter until it reaches a ball. At this stage the outer leaves are generally dead or in the process of drying out. The individual leaf tip is also dead and chlorophyll production is found only as the heart of the rosette is approached. The leaves in the heart will generally be a pale green mottled with dead or dying brown colored tissue. The leaves will have a general appearance of being scalded.

The sixth symptom or climax is reached when all leaves die back to their insertion point on the stem (Fig. 18). The stem itself will begin to die back and will continue until th crowns are reached. If conditions are severe enough, the entire stolon will die (Fig. 18). Dead areas of the grass can be limited to a few stolons or it may cover a wide area (Fig. 20). If growing conditions improve there will often be a regrowth from infested rosettes located on a damaged stolon (Fig. 19).

In many cases the weather or other environmental conditions will improve to the point where the infested grass will go into a stage of regrowth, sending out new leaves which may originate within the rosette. However, the new leaves can still be abnormal in appearance but will exhibit a reasonable green color. If the grass continues to grow and radiates out of the rosette or nodular like conditions or if the mites are controlled or disappear, then the original rosettes will exist for several months if not removed by mowing.

During the course of this research, many mite infestations and extensive and intense rosetting conditions appeared in grass plots and often there was no leaf twisting analagous to drought conditions observed.

In order to find a "knot-like" rosette in normal appearing healthy grass it would often be necessary to use the sense of touch or feel. One of the best methods for locating mite populations would be to gently feel the grass surface with just enough pressure on the hand so that the knots could be felt.

It has been falsely concluded by many of the turf workers that the mites occur only in dry weather. The reason for this belief was the general wilting of large areas coupled with mite symptoms that would stand out to the casual observer during drought periods, and in the wet season very evident symptoms were masked by lush green healthy turf. The feel technique previously discussed

Fig. 10. Healthy Grass Showing Slight Leaf Twisting Brought on by Moisture Deficiency

Fig. 11. Beginning Symptoms of Mite Injury Showing Shortening of Internodes and Leaf Twisting

Fig. 12. Further Progression of Mite Injury Showing Shortening of Internodes but with Leaf Thickness Still Approximately Normal

Fig. 13. Internodes Shortened Even Further with Time and Individual Leaves Becoming Thicker and Shorter

Fig. 14. This is an Advanced Stage of Mite Injury with the Grass Showing the Symptoms Termed "Fan" which Precedes Rosetting

Fig. 15. Beginning of the Stage Known as the "Primary Rosette" which Approaches the Most Advanced Injury Stage

Fig. 16. An Extremely Advanced Stage of Mite Injury Termed "Secondary Rosette" which Precedes Death of the Grass

Fig. 17. Sequence of Symptoms Exhibited by No Mow Variety Bermudagrass. Grass Spike at Far Left is Wilted but Healthy and the Entry at the Far Right is in the Climax Symptom.

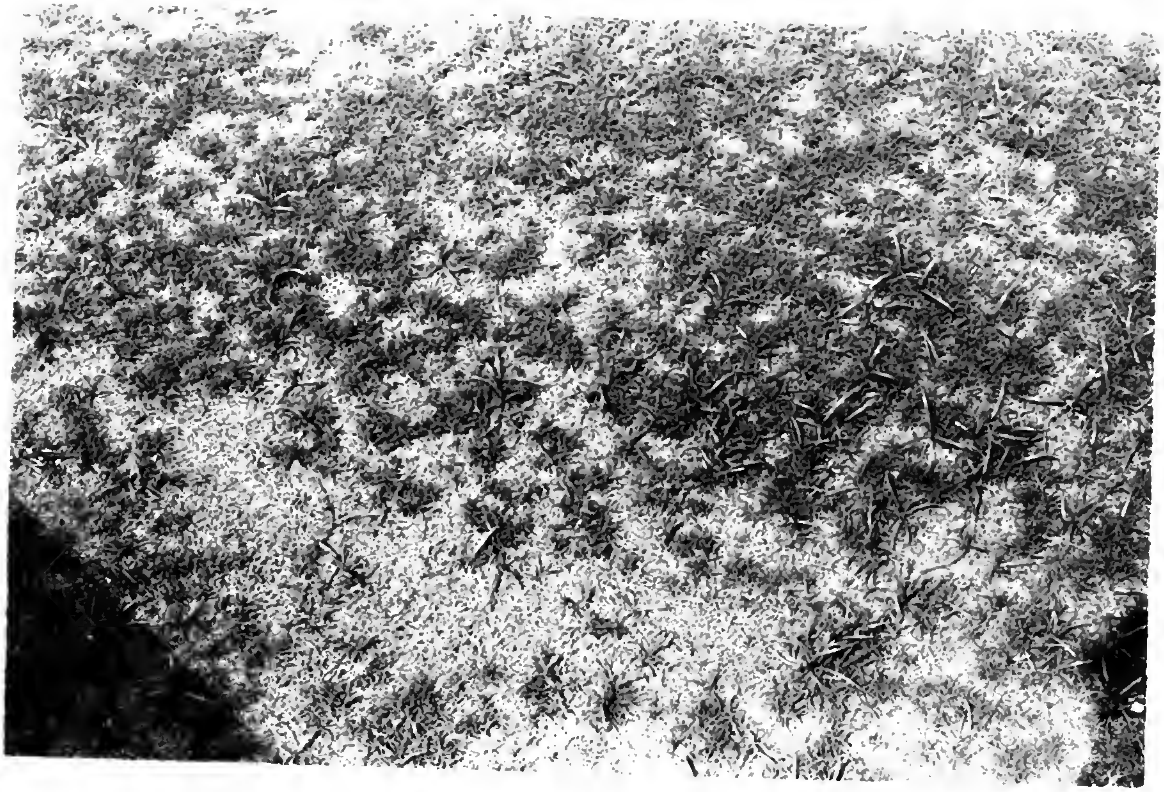

1 2 3 4 5 6 7 8 9 10 11

Fig. 18. Climax Stage of Grass Infested with Bermudagrass Mite Showing Stolon Diebacks

Fig. 19. Regrowth of Grass Coming from Mite Infested Rosettes Along a Stolon of Common Bermudagrass

Fig. 20. Typical Spotted Damage Found in Mite Infested Grass

Fig. 21. An Isolated "Fan" Found Among a Healthy Appearing Area of Grass



proved invaluable in quickly screening large areas for mite populations especially where grass growth was good, thatch heavy and symptoms difficult to see.

Some Mistakes Believed Being Made in Controlling the Bermudagrass Mite

Observations were made on golf courses around the state for 2 1/2 years. The maintenance and improvement operations needed in a successful golf management course are quite large. There are constant problems ranging from a simple top dressing of a green to the complete rebuilding of that structure. Spray operations are important and they take their place in a maze of operations depending upon many variables such as weather, size of the operations' budget, training and background of the superintendant, sequence of attack by a host of insect, weed, or disease agents, course traffic, and many other common day-to-day problems.

There appears to be no set procedure for the control of the Bermudagrass mite. There is no sampling technique available to the course managers or others where they can monitor the mite populations and reach a decision as to timing of spray. The majority of courses observed apply one or more applications of Diazinon on greens, tees and the aprons of these structures sometimes in the spring to early summer depending on geographical location within the state. Spraying is generally done when complaints are voiced by neighboring courses, or when witchbrooming or rossiting can be observed in other areas on the golf course. This control technique can be very costly for the following reasons. First, mite outbreaks can occur on a neighboring golf course when it is planted to varieties that are more susceptible to mite damage. For example, if the fairways and roughs are Common or Ormond varieties which are well-known to be susceptible you would expect to find mites in greater numbers than where the tees and fairways are Tifway (419) the greens are Tifgreen (328) and the roughs native grasses or other vegetation.

A second mistake can be the application of a pesticide when pseudo witchbrooming (leaf twisting) appears. As has already been discussed under Symptomology, this condition can be brought on by an array of reasons with insufficient watering at the proper time being one of the most frequent causes. The lack of sufficient rainfall is common in much of the state during the spring to early summer. Leaf twisting can be observed on any day during this period and first occurs as spotted areas. As the drought continues and the net loss of water from the grass is greater than the gain, leaf twisting which is commonly mistaken for witchbrooming appears as grass temporarily wilts. Bermudagrass demands more water than many grasses and wilts quickly under stress. This can be observed where spots of Bermudagrass exists among grosses like Bahiagrass and St. Augustinegrass. On a hot afternoon, you can observe from quite a distance the spots and perimeters of the Bermudagrass by its leaf twisting wilt whereas the adjacent grasses of other varieties do not exhibit this characteristic until after a longer duration of stress. Golf courses being almost wholly planted in Bermudagrass certainly exhibit this response to heat and drought. As these conditions become persistent, many managers apply pesticide in belief that mites are causing the wilted condition. There can be other reasons for the leaf twisting such as nematodes, Bermudagrass scale and other pest infestations as well as nutritional problems. The soil type should not be overlooked as its water holding capacity varies greatly.

A third mistake is the spraying of the greens. Greens are of course the one area of the golf course that must be kept in the best possible shape if it is to be successful. Maintenance here is often oriented around complete prevention of any pest that could cause damage. No chances are taken because dead spots, grass discoloration or any irregularity that could affect play could be reason for loss of clientele. The greens observed during this research have almost totally been planted to Tifgreen (328). During this study no mites were ever observed infesting the turf on the greens.

During this study it was also observed that grass cut short, 3/16 to 3/8 of an inch, never developed rosettes which harbor the high populations of mites. It was also found that inoculation in the laboratory and in the field of Tifgreen (328) was not successful. Based on these facts and observations, the spraying of greens for mites was a waste of time and money. From this discussion, it should not to be construed that there would not be occasions where miticide applications would not be needed.

In areas other than greens, observations have shown that mites frequent the grass that is common to the lips of sand traps and bunkers. Depending on the variety of grass, these irregular areas are designed to promote hazards to the play of the game as well as add beauty to the course. They are a necessity but present certain difficulties in turf management. It is difficult to mow grass varieties surrounding these hazards which are usually planted in Common and Ormond in a large percentage of the time. For these reasons mite populations will usually be found in the peripheral areas of traps and bunkers.

Due to the difficulty in maneuvering mechanized spray equipment in and around these hazards, the grass is not sprayed and subsequently the mites are not controlled.

In many cases, spraying would have to be done by hand. Many of these bunkers and traps are on the periphery of greens where heavy and cumbersome spray equipment are not allowed.

Another area where mites are usually found are along the margins of the rough as it is approached by the fairways. Roughs are maintained in as many different ways as there are golf courses. Many are planted to the same varieties of grass as are the fairways and the only difference between them are the heights of grass, with the fairways being cut shorter. Some courses allow natural grasses or vegetation to grow in the roughs and they can vary from thick shrublike undergrowth to swamp. Due to maintenance and equipment there is always a margin from a few inches to several feet or more where irregularities of the topography of the fairways allows grasses to grow to greater heights and these areas are where mites are found serving as a source of re-infestation golf courses with unlimited budgets do not spray roughs. Most courses in fact do not spray fairways and hence mites as well as other organisms are allowed to run their cycle.

When fairways are sprayed usually the margins are not covered since the spray machine operator follows the patterns or routes established by the fairways in as straight a line as possible, and to swing in and out to pick up the irregular dips or other spasmodic edges would be a waste of time and spray and would prevent the operator from maintaining any sort of smooth patterns of direction when spraying. It has been observed the mite populations appear to build up in these areas and spread into the fairways from these points and thus creates spotty playing surfaces.

The same problem applies to streams, ponds, lakes or other areas of water, both man-made or natural. Since water hazards are a part of any well designed course it is only natural that they exist at a relatively lower elevation than those surrounding areas of play relegated to more sophisticated managed grass. Slopes which are often quite steep are the result of connecting between these two areas. The rise and fall of water tables also more or less delineates areas where soft or muddy soil exists. Margins around these bodies of water due to slope, mud or both prevent the operation of machinery within these areas. These margins are often the centers of heavy mite populations and damage frequently appear along these slopes and banks.

The use of plants, shrubs and trees are also a very important part of the total golf course. The landscaping plants are often placed along streams, banks, around lakes, or ponds and along margins where the fairway phases into the roughs. In many cases the same variety of grass found in the fairway grows close to these plants. This is an area where mites are almost always found if the golf course is infested. Very few managers employ weed killers or maintain clean cultivation around the bases of the trees or plants. Grass of course grows to heights of several inches and creates an ideal habitat for mites since the rosettes can fully develop due to the absence of mowing. It is difficult to operate sprayers in and around these shrubs. It is a mistake not to control the grass heights and to spray in these infested areas.

Cart paths, bridges, restroom facilities, fences and buildings make up a part of any golf course. The grass in these areas is maintained to a great extent like that found around trees and it is difficult to manage the grass from either a mowing or spraying standpoint. It also appears that the trend is not to spray those areas that are not involved with the actual turf that comes into play. However, these are the areas where the mites are harbored and where the mites are able to maintain their normal life cycles, create rosettes and very large populations can develop.

Temperatures

Introduction

It was observed that mites were found most frequently in taller grass. A study was initiated to determine the temperature of various niches of the golf course surrounding the mite habitats during period of infestation. Since greens which were cut 3/16 to 1/4 inch in height were never observed to have mites, and roughes and fairways cut 3/4 to 1 1/2 inches did, it was desireable to determine if temperature varied enough to have an influence on the absence or presence of mites.

Materials and Methods

The temperatures of numerous golf and turf areas were recorded by using (1) Bailey Instrument Co.'s Model BAT-4 Thermocouple Indicator and (2) Yellow Springs Inst. Co.'s Model 46-TU Tele. thermometer, Thermistor Indicator. The instruments were calibrated before use. The probes were properly placed in the spots where temperature was desired and allowed to remain for several minutes before readings were recorded. Readings were taken in a series and variables such as wind, sun, cloud cover and other environmental factors were noted.

Readings were made of air temperature 6 inches above the turf, turf surface, in the turf thatch, at the soil surface below the turf thatch, and 4 inches below the soil surface. Rosette and leaf temperatures were also taken at various times.

Temperatures of the leaf sheaths and rosettes were taken with the use of a fine needle-shaped thermistor especially designed for taking probe type temperatures.

The thermistor indicator unit used for these measurements had two probes so temperatures could be taken almost simultaneously by the flipping of a switch. The thermocouple indicator had 5 outlets so that temperature readings could be taken in 5 separate locations by simply switching a dial, thus all 5 readings could be made within a matter of a few seconds.

Results and Discussion

From data gathered in the period April 18 through September 26, 1973. The following observations were made.

(1) The air temperature 6 inches above the surface fluctuated widely and depended a great deal on cloud cover and wind. A slight breeze would cause temperatures to drop several degrees. Cloud cover plus a breeze could cause up to 10 degrees temperature drop within 60 seconds. The maximum 6 inch height temperature recorded was 99.5°F on July 25 and a minimum of 80°F on April 18.

(2) The hottest microenvironment tested was the surface of the turf with the maximum recorded being 118.5°F. Temperature tests on the same varity of grass where on side of a plot was kept mowed at 1/2 inch height and the other at 2 inch height were monitored on various dates. The results are as follows.

Temp. of Grass 1/2 inch in height in °F	Temp. of Grass 2 inches in height in °F	Difference in °F
89.5°F	86.5°F	+3.0°F
90.0	84.0	+6.0
89.0	84.5	+4.5
102.5	91.5	+11.0
103.5	94.0	+9.3
89.5	83.0	+6.0
89.5	86.5	+3.5

(3) Temperatures of the thatch were a great deal cooler than surface temperature. Maximum recorded was 99°F on July 25 and a minimum of 80°F on April 18. The variation found was not generally as great as on the surface.

(4) Soil surface temperatures ranged from a maximum of 102.0°F on June 20 to a minimum of [illegible]°F on May 21.

(5) Temperatures taken at a depth of 4 inches into the soil were found to range from a maximum of 76.0°F on April 18 to a minimum of 67.0°F on May 21.

(6) Temperatures taken between the leaf and sheath with termistor probes showed temperatures reached a maximum of 106°F during this test period.

(7) Maximum temperatures taken deep inside rosettes were found to reach 111.5°F.

(8) Rosettes containing mites were found to cool slower than surface temperature. Surface and rosette temperature reaching 111.5°F were artificially shaded. Within 2 minutes the surface temperature had dropped to 91.5°F whereas it took the rosette 10 minutes to reach the same reading. When exposed to the sun the surface temperature gained 9°F within 60 seconds as compared to a 4°F increase in the rosette.

Other readings are listed in Appendix F.

Summary

It was expected that thatch temperatures might have been high enough in grass cut short to prohibit the buildup of mite populations. Temperatures were occasionally slightly higher in the short grass environment as compared to taller grass but more often the reverse was found to be true. The mites were found to live in an environment (rosettes) with temperatures considerably higher than those measured in this test on Bermudagrass plots kept cut at 1/2 to 2 inches in height. Thatch, soil surface and subsoil temperatures were found to vary considerably when compared to air temperature. It was felt that this variation depended on moisture content of the niche being examined as well as the total thickness or mass of grass cover, soil type in which the grass was growing, as well as the amount of dead grass and other organic debris found in the zone between the leaves and roots of the grass. The physical makeup of the niches were known to vary widely and therefore their ability to act as insulators varied. Each niche absorbed heat and released it at a different rate in comparison with others; thus wide temperature ranges were encountered within strata.

Mite Habitats

Many samples of St. Augustine, Bahias, centipede, rye, bent, and other nondiscriminate varieties of grass were collected from areas where infested Bermudagrass was either growing intermingled or in close proximity. Many of these samples were off-color, appeared stunted, and showed signs of leaf twisting. Examination revealed many causes of the grass abnormalities ranging from scale insects to fungus or other reasons. No E. cynodonensis were ever found on any of these samples.

When mites first become evident in turf, they are most often found localized in one or more of the following areas (discussed under Symptomology).

(1) In close proximity to and along fences and edges of buildings (Fig. 22).

(2) In close proximity to water. The water source can be of the still or flowing type. One of the favorite places is several feet from the edge of a small stream or brook that may run through the golf course (Fig. 23).

(3) Close to trees, shrubs and other obstacles (Fig. 24).

(4) On the tip edges of bunkers or sand traps (Fig. 26).

(5) Along sidewalks, roadways and other obstacles that are encountered within the course (Fig.25).

(6) On the gentle slopes or at the base of slopes of tees or greens.

(7) Along the margins of the fairways as they fade into the roughs (Fig. 23).

(8) Spots within the course where obstacles or devices such as irrigation caps may be located (Fig. 27).

During the course of this study, mites were never found from samples taken from greens or putting areas. From evidence discussed under Inoculation, it appears that Tifgreen (328) is resistant to mite attack. This is the variety that almost all putting and regular greens are planted. Also numerous observations shown that greens are kept cut at 3/16 to 3/8 inch height at all times. Observations have strongly indicated that mites are found less frequently on closely mowed areas. As observed under the items listed, areas where mites are found most frequently are those that are not mowed or allowed to grow to more than average heights.

Those golf courses that kept fairways closely mowed were seldom bothered with mites. Even fairways planted in Common or Ormond, both highly mite susceptible varieties many times didn't show areas of infestation even when adjacent roughs may show a high degree of damage. However when areas of the fairways were not mowed or kept at close heights 5/8 to 3/8 inch then damaged areas due to mites would be more prevalent.

Fairways planted in Tifway (419) were reported in numerous cases to have infestations of mites. Field investigations and microscopic examination of the samples revealed problems other than mites as being the cause of yellowing or dead spots. During the entire study, only one rosette was found on Tifway (419) variety.

Observations on the growth patterns and collected samples from the plots during this research yielded all stages of abnormal grass growth caused by mite attack. Mite counts were made from leaves found within the "fan" stages (see description of "fans" and rosettes under Symptomology) of growth resulting from mite attack and compared with mite counts found in the rosettes or later stage of grass injury resulting from mite attack. Results are shown as follows:

Expressed Symptom	No. of Individual Counts	Avg. mite/count	Range
"Fan"	88	279	64-696
Rosette	180	776	272-1728

From this data mites can be expected to be more numerous within the rosettes or cabbage head growth patterns of infested grass. This was to be expected since the "fan" type (as discussed under Symptomology) growth occurs earlier in the sequence of attack and presumably before maximum populations have been reached. It was further noted that as a rosette was examined the numbers of mites found under the sheaths increased as the center of the structure was approached. Counts made from the first few outer leaf sheaths of the rosettes were often lower than those in the fan type structures. Generally the mites were found on the inner surface of the sheaths surrounding the stem, but during heavy infestation or when large compact rosettes were examined the mites occassionaaly were also found on the outside of the sheath. This can be explained by the fact that the growth characteristics of the rosette had reached such abnormal proportions that sheaths are not distinct at this stage and the outer surface of one sheath actually touches the inner surface of another as the point of basal insertions were approached. The maximum numbers were found in the area of juncture between the stem and the sheath. It was believed that this difference in populations can be explained by moisture gradiations from along the sheath. As mite populations increased the upper portions of the leaf sheaths were found to be dryer. As the center of the sheaths were approached moisture of the infested tissue appeared to increase. The microhabitat at the base of the sheath insertion was also very moist. The normal leaf sheath is thin, but becomes thickened as the mite infestation progresses and when the final stages of the rosette is reached the individual sheaths are no longer flat and leaf like but more or less round thick spikes.

Fig. 22. Showing Uncontrolled Growth of Bermudagrass Along Fence

Fig. 23. Edge of Pond with High Growing Bermudagrass

Fig. 24. Trees and Other Structures Where Normal Mowing Operations Do Not Reach

Fig. 25. Sidewalks, Roadways and Other Outcrops Where Grass is Allowed to Grow in Height Due to Difficulty in Mowing

Fig. 26. Edges of Bunkers and Sand Traps Where Grass Growth is Allowed to Reach Several Inches in Height

Fig. 27. Obstacles on the Golf Course Where Grass Cannot be Maintained at Satisfactory Heights

Fig. 23. A Closeup Portion of a Rosette Showing Thick Leaf Growth and the Moist Condition of the Tissue

This round tissue is very tender at the base and contains a great deal more volume of fluids than is found in a normal flat sheath of grass (Fig. 28).

Means of Spread

Little is known about the means of spread of the Bermudagrass mites. However from observations of the patterns of outbreak, it is believed that various mechanical devices aid in the spread of the mites along with wind.

As climatic conditions become favorable the mites have been observed to build up into large populations. These populations are then thought to be spread as follows:

Mowers cut the rosettes and nodules and scatter the mulched remains over a wide area and therefore serve as mechanical inoculators. A form of this method has been successfully used in the laboratory as a means of innoculation of grass. Verti-thinners as well as tires from the various vehicles, golf carts, etc. are also believed to serve as a vehicle of spread since the innoculum would drop off from time to time. Golfer's shoes and playing equipment may also serve as a carrier of the mites from place to place as it does for the weed *Poa annua* L.

Other eriophyid mites have been known to be spread by wind. It is known that fresh cut grass is blown from areas of where it has been cut. Thus a rosette harboring thousands of mites can be blown from several inches to many feet and thus provide a source of innoculum into uninfested areas. Mites infesting rosettes have lived. confined in plastic and paper bags for as long as seven days after being brought into the laboratory and kept at room temperature.

Water appears to be a means of spread not only for perhaps individual mites but also for cut grass particles containing mites as well. Sudden downpours where several inches of water may be deposited in an area within several hours are not uncommon in Florida. This amount of water has a tremendous washing effect as evidence by rings of deposited grass and turf debris at random spots on golf courses.

Associated Organisms

Introduction

During this study it was frequently noticed that mite populations on collected samples would drop from high to very low levels within a few days. Often during a test the mites would disappear from the controls. Examination of the rosettes or other infested grass structures would yield numerous mites and other insects, some of which were believed to influence Bermudagrass mite populations.

A Special Grass Survey (Lick et al. 1955) was run in Monroe, Dade and Broward counties, Florida from July 1, 1954 through March 1955. The purpose of the survey was to collect, identify, and record all arthropods found on turf.

The following organisms were found to be associated with Bermudagrass.

Southern armyworm	Prodenia (Spodoptera) eridania (Cram.)
Bermudagrass scale	Odonaspis ruthae Kot.
Sugarcane scale	Targionia sacchari (Ckll.)
Coleopterous grub	Phyllophaga sp.
Lepidoptera	Crambus teterrellus (Zinck.)
Rhodes Grass Scale	Antonina graminis Mask.
Mole Cricket	Scapteriscus acletus R. & H.
Coreid bug	Chariesterus antennator (Fab.)
Anthocorid bug	Ligurocaris multispinus Stal.
Reduviid bug	Sinea sanguisuga Stal.
Lygaeid bug	Unknown Species
Earwig	Labidura bidens (Oliv.)
mite	Cunaxoides andrei Baker & Hoff.
mite	Amblyseius sp.
mite	Galumna sp.
mite	Scheloribates laevigatus (Koch)

Butler (1963) found the following groups to be associated with Bermudagrass in Arizona.

Suborder Mesostigmata

Laelaptidae

Cosmolaelaps sp.

Aceosejidae

Proctolaelaps sp.

Phytoseiidae

Typhlodromus (*A.*) obtusus group.
These large predatory mites are common.

Amblyseiopsis n. sp.

Uropodidae

Leiodinychus sp.
Nymphs are very abundant in ground litter.

Suborder Trombidiformes

Tarsonemidae

Steneotarsonemus spirifex (Marchal).
This mite occurs on many species of grasses, corn, and related plants throughout the United States. It is also common in Europe where it is a pest of oats. A critical evaluation of its damage to Bermudagrass and other plants has not been made in the United States.

Tydeidae

Several spp.
These are small, soft-bodied mites which appear to be predatory.

Cunaxidae

Cunaxoides andrei Baker and Hoffman

Cunaxoides n. sp.

This and the above species are predatory.

Caligonellideellidae

Holothrognathus crucis Summers and Schlinger

Holothrognathus n. sp.

Tetranychidae

Petrobia latens (Muller), brown wheat mite

Most common in the spring months.

Schizotetranychus eremophilus McGregor

A small spider mite that seems to be generally distributed but never abundant.

Oligonychus pratensis (Banks)

This and *O. stickneyi* cause considerable injury to bermudagrass, particularly seed crops. They are most abundant on the leaves of mature plants and usually during the summer months.

Oligonychus stickneyi (McGregor)

Often found together with *O. pratensis* in mixed infestations.

Cheyletidae

Paracheyletia wellsi (Baker)

A predatory mite.

Eriophyidae

Aceria neocynodonis Keifer

These small white mites live ensconced at the bases of the leaf sheaths. They cause a stunting effect on the grass due to shorter internodes and a general decline of the grass. Since their discovery in Arizona in 1959, they have been found in several other states.

Erythraeidae

Balaustium sp.

Leptus sp.
This and the above species are predatory.

Suborder Sarcoptiformes

These are longer mites, sometimes referred to as beetle mites because of their hard body and general appearance.

Ephilohmanniidae

Ephilohmannia cylindrica (Berlese)

Carabodidae

Tectocepheus sp.

Oribatulidae

Zygoribatula sp.
This species is abundant in the ground litter and becomes noticeable during irrigation when the mites crawl to the upper parts of the grass. Since they inhabit the ground litter primarily, it is doubtful that they cause any injury to the bermudagrass.

Materials and Methods

As the rosettes and other grass structures were examined for Bermudagrass mites many other arthropods were found inhabiting the structure. These arthropods were removed and stored for future identification.

It was decided that a collection of arthropods with special emphasis on other mites would be done on the rosettes and grass structures that were known to harbor the mite. The samples were taken with care not to include the strata that makes up the root zone or zone of accumulated organic debris that lies between the soil and the healthy grass leaves. Samples included the crown, stem, and grass leaves. Samples were also taken from Tifway (419) and Tifgreen (328) two varieties never found to be infested with the Bermudagrass mite. Cromroy and Reinert (1974) sampled the root and organic layer strata around Bermudagrass thus it was omitted from this research.

The samples were placed in plastic bags, sealed, and kept under air conditioning. The arthropods were extracted by using a modified Tullgren apparatus (Krantz 1970). The apparatus was run a minimum of 48 hours or until the grass sample was dry. The extracted mites and other arthropods were removed and kept in 80% ethyl alcohol. The mites were extracted and mounted by acarology technicians using Hoyers media.

The mites were coded and identified by Dr. H. L. Cromroy, Dept. Entomology and Nematology, University of Florida. Other arthropod specimens were identified by the specialists with the Florida Department of Agriculture and Consumer Services Division of Plant Industry or taxonomic specialists with the Museum of Natural History, Washington, D. C.

Results and Discussion

The concern of this phase of the research was to determine the predaceous species found in the grass stratum with the Bermudagrass mites. All samples were taken from grass with none from the soil strata. Since the sampling technique is primarily qualitative, the number of specimens per species will be indicated by either F for 3 or less specimens or M for 4 or more specimens per sample. There is still very little known on the nutritional requirements of the predaceous mites. The most extensive study by Brickhill (1958) on tydeids indicated that one species *Lorryia ferrulus* Baker could subsist on the eriophyid, *A. sheldoni*, but not reproduce. Muma (1961) listed one predaceous tydeid, *Pronematus* sp., on citrus, 8 species of cunaxids, one macrochelid and 11 species of Phytoseidae. However as previously stated, there is very little known on feeding behavior of these groups.

Tables 9 and 10 list the most frequent predatory groups and their location. It should be noted that species overlap in certain locations and where there are many predators of one species there tends to be an equally large number from another species. The only exception is the family Eupodidae. This family was found in only two locations. The most widely distributed species was *Neocunaxoides andrei* (Baker and Hoffman) found in 15 sites which differs considerably from Muma's (1961) work which indicated it to be very rare in citrus collections. The two tydeid species were the next common collected species being found in 13 sites. The most common family, found in almost all sites, was a non-predaceous group, Uropodidae supposedly fungivores (Krantz, 1970). This study was only a beginning into the very complex ecology of turfgrass populations pointing out the most numerous predators. Future research should be aimed at the determination of effect and rate of predation on phytophagous grass feeders.

Table 9. Predaceous Species of the Suborder Prostigmata Collected from Samples with their Location

Family	Species	Locale* and Number of Specimens
Cunaxidae	Neocunaxoides andrei (Baker and Hoffman)	4(F), 5A(F), 6(F), 8A(F), 16(F), 18(F), 19(M), 24(F), 25(M), 27(F), 28(F), 29(F). 30(F), 34(M), 3[illegible](M).
	Cunaxa simplex (Ewing)	19(F), 25(F).
	Dactyloscious sp	18(F), 29(F).
Eupodidae	Eupodes near ocellatus	8A(F), 25(M).
Tydeidae	Tydeus pertydeus tuttlei Baker	2(F), 5A(F), 6(F), 8A(F), 8B(F), 10A(F), 12(F). 16(M), 18(F), 25(F), 31(F), 34(M), 35(M).
	Paralorryia near italica	5A(M), 5B(M), 6(F). 16(F), 18(F), 26(F), 27(F), 30(F), 31(F), 32(F), 34(F), 35(M).

*Locale is given by number code which is detailed in appendix.

Table 10. Predaceous Groups of the Suborder Mesostigmata Collected from Samples with their Locations

Family	Species	Locale and Number of Specimens
Macrochelidae	<u>Macrocheles muscaedomesticae</u> Sopoli	4(F), 19(F), 21(F), 23(F), 27(F)
	<u>Macrocheles</u> near <u>rothamstedensis</u>	22(F), 26(F), 27(F)
Phytoseidae		5B(F), 8A(F), 8B(F), 19(F), 34(M), 35(M)

RECOMMENDATIONS

The following recommendations are made based on the control of the Bermudagrass mite only and the writer is fully aware that some parts of the program may not be practical under present conditions.

The integrated control program is composed of several areas each of which will be discussed.

I. Bermudagrass varieties to be utilized:

A. Greens--should be planted in Tifgreen (328) variety. This variety appears to be resistant to mites and is desireable for putting surfaces.

B. Tees--should be planted to Tifway (419). This also appears to be a mite resistant variety.

C. Fairways--should be planted in Tifway (419) variety.

D. Roughs--if these areas are to be maintained with Bermudagrass it would be recommended that Tifway (419) be used. Common, Ormond, and St. Lucie varieties should be omitted. If grass had to be utilized and Tifway (419) could not be used then a grass such as St. Augustine or another type would be recommended. Roughs planted in trees, native plants or other vegetation would also be recommended.

II. Maintenance of established varieties

1. Mowing--practices should be aimed towards keeping grasses cut as short as practical which would still have a good appearance and be suitable for good golf play. Bermudagrass mite infestation generally decreases with a decrease in grass height.

   a. Greens--no recommendation. The current program appears to be excellent.

   b. Fairways--planted in Ormond, common, or St. Lucie or other known mite susceptible varieties must be kept mowed short, preferably 3/4 of an inch in height or less.

   c. Roughs--cut as short as possible if susceptible varieties are used.

   d. Shrubbery and trees--grass should be removed from around these structures to a distance where it can be mowed. Removal can be accomplished by cultivating techniques or by the use of proper herbicides. If removal is not practiced then hand mowing must be done in order to keep the grass at fairway heights.

   e. Fence areas, borders to buildings, sidewalks, roads and other structures--should be maintained so grass does not grow taller than fairway heights. Clean cultivation or herbicide use is recommended.

f. Areas bordering ponds, lakes, streams and/or other structures where the topography is likely to be sloped or undulating to the extent so as to prevent mowing should be planted in non-susceptible grass varieties. The plants should range outward to an extent where mowers can be run without objection.

g. Bunkers and sand traps--the primary recommendations is to use Tifway (419) so that the margins and lips of these structures can be allowed to grow several inches in height without fear of mites. In order to add beauty to a golf course it is mandatory that the grass around the lips of traps and bunkers be several inches in length. Attempts to mow these areas short results in unsightly grass. These structures are constructed to be irregular and thus low mowing causes "scalping" to occur at numerous specific spots.

h. Good fertility and water programs are recommended. Infested grass is placed under added strain if the turf is to be subjected to nutritional deficiencies and dry conditions. Bermudagrass mites have been found to readily attack luxurious growing grass but seldom become a problem during the wet seasons. Complaints of damage generally occur in the dryer spring months in which the grass had not reached its peak growth rates following the winter period. Healthy grass is by no means immune from attack but is often able to outgrow or "live with" the pest.

III. Use of the mite survey--a proper mite survey is necessary if control approaches are to be best utilized. If microscopic examination is to be employed then it is recommended that it be done utilizing a dissecting type microscope capable of at least 30X magnification. Hand lenses are not recommended. The survey should include the entire golf course and added emphasis should be placed in the stress areas discussed under (Some Mistakes Believed Being Made in Controlling the Bermudagrass Mite).

The surveyor should be familiar with the sequence of symptoms caused by the mite. The use of the "touch" method can also be utilized in order to locate distorted rosettes. The use of the aforementioned method is often sufficient to find infested spots and is a helpful substitute for actual microscopic evaluation.

IV. Use of pesticides

A. It may become necessary to use chemicals for control of the mite from time to time. If the survey method is efficiently employed spot spraying can be utilized. Mite infestations can generally be found within the spots and niches previously explained and therefore can be controlled by spot treatment. From the results obtained during this study chemical control programs for the Bermudagrass mite would be recommended as follows:

1. Greens--normally would not receive miticide treatments since nearly all golf courses within the state are presently planted in Tifgreen (328) an apparent resistant variety. Present mowing heights of 3/16 to 3/8 of an inch is thought to further diminish the chances of infestations.
2. Fairways--should be surveyed and spot treated before infestations become heavy if planted in Ormond, St. Lucie, or common variety. If planted in Tifway (419) no treatment should be necessary.
3. Roughs should be surveyed thoroughly for infestations if planted in susceptible varieties and spot treated before mites can infest large areas.
4. Sand trap and bunker margins should be treated when mites are observed. Since the grass on

the edges of these structures must be allowed to grow longer they are consistently a source of infestation when planted in varieties other than Tifway (419).

5. Areas surrounding shrubs, trees, bordering structures, etc. should be surveyed and treated immediately following observation of mites.

B. The spot spray or the treatment of specific areas is thought to accomplish the following desirable results:

1. It would tend to utilize less labor.
2. Less pesticide would be used in the environment with less monetary cost involved.
3. From collections made and discussed under Associated Organisms, there is a strong possibility that blanket applications of a pesticide could effect populations of predacious mites so that more harm than good would occur. The spraying of selected areas would not seriously upset but may promote beneficial forms.

The preceeding recommendations however are not intended to imply that blanket pesticide applications should not be made if infestations are spread over large areas. Under these conditions, blanket treatment would be more economical.

Often infestations have been observed where more than one application had to be used in order to stop damage. If populations occur in such a manner and multiple applications are to be made, it is suggested that each application should be spaced about 7-10 days apart in order to control the mites which were in the egg stage during of the previous treatment. However, before repeat sprays are used, care should be taken to microscopically examine known infested areas since dead mites can take several days to lose color and decay and their body presence alone is not always a sufficient criterion to assume them alive. Observation of the mites at 30X power is sufficient to pick up body movement. Upon being exposed to light, living mites will begin to move.

The rosettes will often remain for several weeks after the infestation has disappeared. Rosettes that have reached a point where death of the grass is imminent will often take on a second growth if the mites disappear or are controlled. Care should be taken in treating the mites rather than for symptoms.

As a result of this research, there is no reason not to expect good chemical control from the use of diazinon. From observations of its use in the field and from knowledge of the microenvironmental habits of the Bermudagrass mite it is recommended that an acceptable wetting agent be used in conjunction with diazinon or alternative miticides. It is felt that the reduction of surface tension of the finished spray would aid in carrying the miticide into the tight space between the leaf and stem which is occupied by the mite.

Control of Other Organisms as a Control for Bermudagrass Mite

During this study, nematodes and insects particularly the Bermudagrass scale were often found attacking grass in association with the Bermudagrass mites. It was observed that the multiattack of these pests often reduced grass vigor so that dieback appeared. Control of other pest organisms with pesticides often promoted regrowth of grass that also had Bermudagrass mite infestations. Grass can frequently tolerate mite attack and outgrow it if it is not simultaneously weakened by other organisms.

Preliminary studies indicate that aldicarb and phenamiphos, which are primary nematicides, also have insecticidal and miticidal properties. Phenamiphos has currently received EPA clearance on turfgrass, and aldicarb can be used in Florida under experimental conditions. The latter chemical is also a waiting federal approval. These two compounds should possibly serve as a means of mite and nematode control and would also offer some control of multiorganisms which would be highly desirable in the overall integrated pest control program. Both compounds are systemic in their mode of action and aldicarb currently is considered as a miticide. Systemics could be desirable since they might not be expected to harm the predacious mite complex as severely as would some other miticides.

Reduction of Overwintering Habitats

Mites are known to damage turf throughout the year in southern Florida. In the northern part of the state they go unnoticed until late spring since the turf is in a dormant stage in the winter or has been overseeded. The Bermudagrass mite was found in mid-February, 1974, on Common variety of Bermudagrass in Gainesville, Florida. The infestations were observed where the grass had grown to several inches in height. The grass had responded to the attack by forming fans and early stages of rosettes. The grass observed was found along the south side of building edges and other structures where it had been protected from the cold and was in a stage of good growth and color. It would be recommended to keep grass cut short in areas where winter die back did not occur.

In making these recommendations the writer is aware that turf management is concerned with many problems besides Bermudagrass mite control. It is also understood that many of the individual facets of integrated control might not be economical or practical. For instance to cut grass shorter will require management to use more fertilizer and water than if grass is allowed to grow taller. However this study was primarily aimed at learning of the Bermudagrass mite habits so that a better approach to its control could be employed.

The research on the Bermudagrass mite has led to the following generalized conclusions. One of the goals was to determine if a better control program could be developed. It has been more or less an accepted belief by many laymen in the past that a better control program would consist of one or more of the following: (1) an increase in the amount of material being used; or (2) an increase in the number of applications; or (3) to find another pesticide that would do a better job on the pest in question.

Testing of candidate materials was a part of this study and the use of chemical control is still the mainstay in mite control programs. However, it is felt that from the result of this study that an integrated control approach should be considered the turf industry in Florida.

CONCLUSIONS

The following conclusions are drawn from this research:

(1) Ormond, Tiflawn (T-57), common, No Mow and St. Lucie varieties were successfully inoculated in the laboratory with Bermudagrass mites and developed definite mite symptoms.

(2) Tifgreen (328) and Tifway (419) varieties of Bermudagrass which had numerous attempts of inoculation with Bermudagrass mites did not show symptoms known to be associated with grass that has been infested by the mites.

(3) Mites were found to cause growth abnormalities in grass. The symptoms differed from one another and followed a definite injury sequence.

(4) Mites were found to occupy certain niches on golf courses and generally could be found in these areas if infestations existed. These niches can best be described as those areas where mowing and spraying maintenance missed.

(5) Temperature studies did not indicate temperature to be a factor in the absence of mites on the suspected mite resistant varieties Tifgreen (328) and Tifway (419).

(6) Certain cultural techniques as well as use of resistant varieties of grass and good turf management

practices indicate that they play a large role in determining mite infestation and damage to golf courses.

(7) Chemical tests indicate that aldicarb, diazinon, and phenamiphos are satisfactory chemical control agents for Bermudagrass mites.

(8) Certain juvenile hormones showed no significant influence in reducing mite populations either as an adulticide, nymphicide or ovicide.

(9) Associated arthropods are suspected of playing a large role in influencing Bermudagrass mite populations.

FURTHER RECOMMENDED RESEARCH

In conclusion it has become evident that more information is needed concerning the Bermudagrass mite, *E. cynodoniensis*. The following areas need more investigation:

1. A better sampling method is the number one problem. The current methods are time consuming and difficult. Samples must be processed through lengthy procedures and the mites must remain out of their natural habitat for long periods of time. The efficiency percentage of extraction methods are not known and thus it is hard to assess total populations.

2. More study is needed on the ecology of the microenvironment of the mite. This information could be useful in the application and placement of control agents.

3. There is a need for more in-depth study of the predator-parasite complex of the pest.

4. An assessment of annual damage to the turf industry by the mite as well as time and money expended on the problem is needed.

5. There is a need for an in-depth study of the biology and life cycle of the Bermudagrass mite under Florida conditions. This should include overwintering studies in the geographical areas where grass is dormant during the winter.

6. A specific physiological study is needed to determine the reason the grass develops with the symptoms caused by mite infestation. This study should include the reasons for apparent resistance by some varieties of Bermudagrass.

7. A total study of Bermudagrass mite dispersion and the reasons or conditions that activates it about would be very useful.

8. More efficacy data is needed on aldicarb and phenamiphos. These compounds are nematicides and were found to give Bermudagrass mite control, thus they could serve as a dual control agent and may work well in an integrated control program.

APPENDICES

APPENDIX A

The label from Miller Chemicals and Fertilizer Corporation, P. O. Box 333, Hanover, Pa. 17331

20-20-20 Nutri-Leaf Soluble Fertilizer

Total Nitrogen (N)	20
Nitrate nitrogen 5.95	
Ammonium nitrate 4.67	
Water soluble organic nitrogen. 9.38	
Phosphorus as P_2O_5 phosphoric acid . . .	20
Potassium as K_2O	20
Boron from borax as B.	.0288
Molybdenum from molybdic acid as Mo.	.0256
Magnesium as Mg. (Water soluble)	.0251
Manganese as Mn. (Water soluble)	.0781
Copper as Cu	.0064
Iron as Fe	.0051
Zinc as Zn	.0046

Potential acidity equivalent to 600 lbs. calcium carbonate per ton.

APPENDIX B

DELRWOOD PESTICIDE TESTS

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	Observed f value
		Analysis of Variance Table		
Reps	3	49.485	16.495	12.64 sign
Treatments	6	32.226	9.371	4.12* sign
Time	2	0.613	0.306	n.s.
Treat X Time	12	16.096	1.340	1
Residual	60	78.327	1.305	
Total	83	176.747		

*Significant at the .05 level

Means (12 observations)

	Control	1 phenamiphos	2 aldicarb	3 trichloroton + oxydemeton-methyl	4 disulfoton	5 fensulfothion	6 propoxur
X	0.33	1.00[a]	1.42[a]	0.792[a]	-0.292[b]	0.629[a]	-0.420[b]

significant

Diff. @ 0.05 level with Dunnett's test.

APPENDIX C

PALMAIRE PESTICIDE TESTS

Table of Transposed Data Using log (1 + y) or $\sqrt{1 + y}$

Mite Counts									
	Days after Treatment								
	14				28				
Treatment	Rep 1	Rep 2	Rep 3	Tot.(14)	Rep 1	Rep 2	Rep 3	Tot.(28)	Tot.(T)
Control (A)	2.356	2.753	1.623	6.732	2.344	2.480	0.788	5.602	12.334
Aldicarb	1.903	0.602	1.623	4.128	0	0	0	0	4.128
Dialifor	0.477	2.312	0.778	3.567	2.207	1.643	3.011	6.861	10.428
Diazinon	0.477	2.542	2.149	5.168	0	0	0	0	5.168
Trichlorfon + demeton-methyl	2.398	1.544	2.464	6.406	2.664	2.901	2.676	8.241	14.647
Phenamiphos	2.511	0.699	2.474	5.684	0	0	2.479	2.479	8.163
Disulfoton	1.568	2.483	2.861	6.912	2.587	1.491	0	4.078	10.990
Fensulfothion	2.971	2.933	2.658	8.592	0	0.778	3.108	3.886	12.478
Oxamyl	1.934	2.408	2.691	7.033	1.114	2.207	2.083	5.404	12.437
Fentine Hydroxide	2.967	2.629	2.243	7.839	2.929	2.716	2.514	8.153	15.992
Totals				62.061				44.704	106.765
Control (B)	2.881	2.900	2.623	8.404	2.729	2.961	2.456	8.146	
Totals (Control (B)				8.404				8.146	16.550

Control A means 2.0557

Control B means 2.7580

Adjusted mean 2.4070

Palmaire Tests (continued)

Analysis of Variance Table

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	Observed F Value
Total	64	65.579		
Days	1	5.022	5.022	
Treatments	9	22.136	2.460	3.73*
Days X Treatments	9	12.053	1.339	2.03
Residual	46	27.738	0.603	

*Significant at .05 level

Dunnett's test = d = 2.51 $\sqrt{0.603\ (1/6 + 1/12)}$ = 0.974

Combined-control mean	= 2.407
Dunnett's factor	-0.974
	= 1.433

Any treatment mean less than 1.433 is significant over control.

Treatment means--

Aldicarb	Dialifor	Diazinon	Trichlorfon + demeton-methyl	Phenamiphos
0.680*	1.738	0.861*	2.441	1.361*

Disulfoton	Fensulfothion	Oxamyl	Fentine Hydroxide
1.832	2.080	2.073	2.665

APPENDIX D

STATISTICAL ANALYSIS FROM DATA ON INVERRARY GROWTH REGULATOR TESTS

Analysis of Variance Table

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	Observed F Value
Total	27	1,923,149	71,228	
Blocks	3	329,642	109,881	
Treatments	6	1,301,936	216,989	13.40**
Error	18	291,571	16,198	

**Significant at the 0.01 level

Dunnett's test = d = 2.48 $\sqrt{2(16,198/4)}$ = 223.19

Control means = 623.25
Dunnett's factor -223.19
400.06

Any treatment mean less than 400.06 is significant over control.

Treatment means--

2R 793 = 617.00	2R 1829 = 598.75
2R 856 = 478.25	2R 1859 = 777.50
2R 918 = 1142.00	2R 1888 = 459.50

Duncan's Multiple Range Comparison of Growth Regulators with One Another

Means:

2R-918	2R-1859	2R-793	2R-1829	2R-856	2R-1888
1142.00	777.50	617.00	598.75	478.25	459.50
c	b	ab	ab	a	a

APPENDIX E

Taken from Farm Chemicals Handbook 1975. Meister Publishing Company, Willoughby, Ohio.

Common Name	Chemical Name	Common Name	Manufacturer
Aldicarb	2-methyl-2(methylthio) propionaldehyde O-(methyl-carbamoyl)	Temik	Union Carbide
Action -	Systemic insecticide, acaracide and nematocide		
Dialifor	O,O-diethyl S-(2-chloro-l-phthalimido-ethyl) phosphorathioate	Torak	Hercules
Action -	Insecticide, Miticide		
Diazinon	O,O-diethyl O-(2-iso-propyl-4-methyl-6-pyrimidinyl) phosphorothioate	Diazinon	Ciba-Geigy
Action -	Insecticide, Miticide		
Disulfoton	O,O-diethyl S-(2-ethylthio-ethyl) phosphorodithioate	Di-Syston	Chemagro Div. Bay Chem. Corp.
Action -	Systemic Insecticide, Acaracide		
Fensulfothion	O,O-diethyl O-[p-(methyl-sulfinyl) phenyl] phosphorodithiate	Dasanit	Chemagro
Action -	Systemic Nematicide-Insecticide		
Fentine Hydroxide	Triphenyltin hydroxide	Duter	Thompson-Hayward

Common Name		Chemical Name	Common Name	Manufacturer
	Action -	Fungicide and exhibits antifeeding properties for surface-feeding insects		
Oxamyl		Methyl N'N'-dimethyl-N-[(methylcarbamoyl) oxy]-1-thioaxamimidate	Vydate L	DuPont
	Action -	Insecticide, Nematicide		
Phenamiphos		Ethyl 4-(methylthio)-m-tolyl isopropylphosphoramidate	Nemacur	Chemagro
	Action -	Systemic Nematicide		

APPENDIX F

TEMPERATURE-TESTS

Results of Temperature Readings in °F
Max. and Min. recorded for each niche during test

Ranges											
[illegible]	Grass [illegible]	Thatch	Soil Level	4" Below Surface	Area Tested	Grass Variety	Date	Time EDT	Approx. Grass Height		Other Measurements in °F
88.[illegible]	97.[illegible]-111.0	82.[illegible]-86.0	86.0-91.5	7[illegible].5-70.0	Tee	Tifway 419	4/18/73	12:00 N.	3/8"		
[illegible].0-87.0	9[illegible]	80.0-89.5	[illegible].0-[illegible].5	73.0-73.3	Green	Tifgreen 328	4/18/73	12:25 PM	3/16"		
[illegible]	[illegible]-111.0	[illegible].0-[illegible]	[illegible].5-101.0	71.5-71.5	Rough	Common	4/18/73	12:[illegible] PM	2"	Rosette	10[illegible].0 F
[illegible]	92.[illegible].5	83.5-[illegible].0	90.5-92.0	68.0-69.0	Green	Tifgreen 328	5/21/73	1:25 PM	3/16"		
[illegible]	[illegible].0-73.0	81.0-81.0	86.0-87.5	67.0-67.0	Fairway	Tifway 419	5/21/73	1:40 PM	1/2"		
[illegible]	95.0-[illegible].0	8[illegible].0-[illegible].5	8[illegible].0-84.5	68.5-69.0	Tee	Tifway 419	5/21/73	3:25 PM	3/8"		
[illegible]	10[illegible]-10[illegible].5	97.5-10[illegible].0	[illegible].5-85.5	69.5-69.5	Rough	Common	5/21/73	3:40 PM	2"	Sheath	99.5°F
97.5-90.0	95.5-97.0	93.5-95.5	80.0-8[illegible].5	71.5-71.5	Rough	Common	6/6/73	3:45 PM	4"	Rosette	102.5°F
[illegible].5-79.0	[illegible].5-91.5	[illegible]-97.0	[illegible].5-94.5	69.5-70.0	Fairway	Ormond	6/6/73	3:50 PM	1/2"		
98.[illegible].5	[illegible].0-96.0	94.5-95.0	[illegible].5	69.5-72.5	Green	Tifgreen 328	6/9/73	4:00 PM	3/16"	Sheath	93.5°F
91.0-93.0	10[illegible].0-105.5	92.0-92.5	93.5-102.0	70.0-70.5	Green	Tifgreen 328	6/20/73	2:30 PM	3/16"	Sheath	97.0°F
[illegible].0-91.0	91.5-102.5	95.0-97.0	[illegible].5-92.0	71.0-71.5	Tee Apron	Tifway 419	6/20/73	1:00 PM	1 1/2"	Sheath	103.0°F
[illegible]-93.5	91.5-102.5	93.0-95.5	[illegible].0	73.5-74.0	Rough	Common	6/20/73	4:10 PM	2"	Sheath	93.0°F
[illegible].5	[illegible].0-105.5	95.0-95.5	86.5-86.5	70.0-70.5	Fairway	Common	7/25/73	11:05 AM	1/2"	Sheath	105.0°F
94.0-[illegible].5	10[illegible]-105.0	[illegible].0-87.5	92.5-94.5	71.5-72.0	Green	Tifgreen 328	7/25/73	12:15 PM	3/16"	Sheath	9[illegible].5°F
[illegible].5	11[illegible].5	8[illegible].5-91.	[illegible]-95.0	71.0-71.5	Rough	Common	7/25/73	1:20 PM	3"	Rosette	111.5°F
[illegible].5	112.5-118.5	97.0-99.0	94.0-95.5	71.0-72.0	Fairway	Common	7/25/73	1:40 PM	3/4"	Rosette	106.0°F
89.5-90.5	[illegible].5-10[illegible].5	[illegible].0-93.5	91.5-92.0	70.5-71.0	Rough	Common	9/26/73	2:20 PM	4"	Rosette	109.0°F
[illegible].0-91.0	10[illegible].0-106.5	93.0-96.5	92.5-93.0	71.0-71.0	Fairway	Tifway 419	9/26/73	2:35 PM	3/4"	Sheath	100.5°F
[illegible].5-92.0	100.5-105.0	95.0-96.5	99.5-101.0	72.0-72.0	Green	Tifgreen 328	9/26/73	2:50 PM	3/16"	Sheath	95.0°F

APPENDIX G

LEGEND FOR ASSOCIATED ORGANISMS

	Date	Locations	Grass Variety Collected From
1.	4-18-73	Pompano Beach, FL	Tifgreen (328)
2.	4-18-73	Pompano Beach, FL	Ormond
3.	9-7-73	Naples, FL	Common
4.	9-5-73	Naples, FL	Common
5.	5-17-73	Pompano Beach, FL	Ormond
6.	5-17-73	Pompano Beach, FL	Ormond
7.	10-2-73	Lauderhill, FL	Tifway (419)
8.	10-2-73	Lauderhill, FL	Common
9.	9-4-73	Sarasota, FL	Tifgreen (328)
10.	9-4-73	Sarasota, FL	Tifgreen (328)
11.	9-5-73	Naples, FL	Tifgreen (328)
12.	9-7-73	Naples, FL	Common
13.	9-7-73	Naples, FL	Common
14.	7-4-73	Wildwood, FL	Common
15.	10-2-73	Lauderhill, FL	Tifway (419)
16.	10-3-73	Lauderhill, FL	Common
17.	7-2-73	Gainesville, FL	Tifway (419)
18.	4-18-73	Pompano Beach, FL	Ormond
19.	6-11-73	Jacksonville, FL	Ormond
20.	6-11-73	Jacksonville, FL	Ormond
21.	6-11-73	Jacksonville, FL	Ormond
22.	6-11-73	Jacksonville, FL	Ormond
23.	6-11-73	Jacksonville, FL	Ormond

	Date	Locations	Grass Variety Collected From
24.	2-8-74	Hollywood, FL	Ormond
25.	2-8-74	Hollywood, FL	Ormond
26.	2-8-74	Hollywood, FL	Ormond
27.	2-9-74	Lauderhill, FL	Common
28.	4-18-74	Lauderhill, FL	Common
29.	4-18-74	Lauderhill, FL	Common
30.	4-18-74	Lauderhill, FL	Common
31.	2-10-74	Tifton, GA	Common
32.	4-18-74	Lauderhill, FL	Tifgreen (328)
33.	5-30-74	Lauderhill, FL	Common
34.	5-30-74	Lauderhill, FL	Common

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BIOGRAPHICAL SKETCH

Freddie Allen Johnson was born on August 5, 1938 in Tampa, Florida. He graduated Salutatorian from Jennings High School, Jennings, Florida in 1957.

He attended the University of Florida and received the BSA degree in Entomology with high honors in 1962. He entered graduate school under an NDEA Fellowship and received the MSA in Entomology with a minor in agronomy in December, 1964. After completion of course work for the Ph.D. in June of 1965, he was employed as Entomologist and Agricultural Consultant for Florida East Coast Fertilizer and Chemical Company until December 31, 1970.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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