THE BIOLOGY AND CONTROL OF THE SPIDER MITES *TETRANYCHUS SCHOENEI* MCGREGOR AND *T. CANADENSIS* MCGREGOR

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THE BIOLOGY AND CONTROL OF THE SPIDER MITES TETRANYCHUS SCHOENEI MCGREGOR AND T. CANADENSIS MCGREGOR

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PREFACE

The spider mites Tetranychus schoenei McGregor and T. canadensis McGregor are becoming more of an economic problem to the Oklahoma farmer every year. Many plants are hosts for both species and they are reportedly biologically and morphologically similar to such an extent that many writers have suggested they may be the same species.

Because of the paucity of information, research data were accumulated to elucidate the biological and taxonomic factors of both species. The immediate effectiveness and residual action of acaricides was determined for both species.

Gratitude is expressed to Dr. D. E. Howell, under whose direction the work was conducted; to Mr. R. Furr for his assistance in checking species and his suggestions of rearing and checking methods; to Mr. Charles F. Henderson, Entomologist, U.S.D.A., for the loan of materials to construct rearing cages; to Dr. D. E. Bryan for his guidance in doing the research work and to Dr. F. A. Fenton and Dr. W. H. Irwin for their advice in preparing this report.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

INTRODUCTION

The spider mites Tetranychus schoenei McG. and Tetranychus canadensis McG. are recently recognized pests of many cultivated crops in central and eastern United States. Cotton, apple, plum, pecan and elm are common hosts. They injure the hosts by piercing their leaves and removing sap which results in stippling and bronzing of the leaves. When populations are heavy, complete defoliation may occur.

Little information was available on these important pests; their biology under Oklahoma conditions was unknown, their species status was uncertain and no information was available on the effectiveness of available acaricides. The writer became interested in these mites and a research program was developed to provide information on some of these problems.

Three lines of approach were studied. Life history studies were made to compare the two species under the same conditions. Reciprocal mating tests were also made because it had been reported that they were probably sub-species or even the same species. Acaricide experiments were also made on them because few chemical controls have been reported as tried on these particular species.

The data are presented on the results of extensive laboratory research under constant and variable temperature conditions conducted from July 1954 to June 1955.

REVIEW OF THE LITERATURE

TAXONOMY

The spider mites Tetranychus schoenei McG. and T. canadensis McG. belong to the genus Tetranychus erected by Dufour in 1832 (McGregor, 1919) and the family Tetranychidae erected by Donnadieu (1875).

Tetranychus schoenei was described by McGregor (1941) from material collected on apple in Virginia. Tetranychus canadensis was described by the same author (1950) from apple leaves in Ontario, Canada. The presence of a small but obvious mediodorsal spur on each of the empodia was considered by McGregor (1919) to be a character worthy of generic value, and he proposed the generic name Septanychus for species exhibiting this character. McGregor (1950) included these two species in Septanychus, but most authors (Baker, 1952, Baker and Pritchard, 1953, Atcheson, 1953, etc.) do not consider this character worthy of generic consideration. Septanychus is therefore regarded as a synonym of Tetranychus.

BIOLOGY

Cagle (1943) has made the only biological study of T. schoenei. He reported that the incubation period ranged from three days at an average temperature of 81.6°F. to 25 days at an average temperature of 52.6°F.

The duration of the larval stage ranged from one day at an average temperature of 78.3°F. to seven days at an average temperature of 59.3°F. The feeding period required a little over half and the quiescent period a little under half of the total developmental time of the larvae.

The protonymph stage ranged from one day at an average temperature of 80.3°F. to 11 days at an average temperature of 55.3°F. The feeding and quiescent periods each lasted about half of the stage.

The deutonymph stage ranged from one day at an average temperature of 78.3°F. to 19 days at an average temperature of 47.6°F. A little over half of the stage was spent in the quiescent period.

The total time of development from hatching to adult was five days at an average temperature of 80.7°F. to 34 days at an average temperature of 51.0°F.

The preoviposition period ranged from one to five days and the average number of eggs per female was 36 in 1941 and 37 in 1942.

Cagle (1943) reported the duration of a generation was from 50 to 65 days with a generation beginning when the first egg was deposited and ending when the last mite died or was lost.

Lienk and Chapman (1951) made preliminary observations on the biology of T. canadensis. They called it the four-spotted spider mite and reported that the general rate of development was similar to T. bimaculatus Harvey. The authors also reported their habits and injury similar to each other. Atcheson (1953) reported that in Maryland they were found feeding on American linden in July and August, but by the last of October only hibernating forms of the females were found in the soil at the base of the trees.

Baker and Pritchard (1953) reported the known hosts of schoenei as apple, black locust, cotton and brambles while those of canadensis were apple, cotton, rose, elm, linden, plum, horse chestnut and osage orange. In Oklahoma, Furr (1955) collected canadensis from elm (most common host), cotton, apple, maple, mulberry, corn (greenhouse only), plum, poison ivy, ragweed, locust, osage orange and blackberry. He collected schoenei from persimmon, plum, blackberry, cotton, sumac, wild rose, locust, cottonwood, mulberry, apple, redbud, lantana, elm, osage orange, pecan, hackberry, and cultivated rose.

Many writers have indicated that T. schoenei and T. canadensis are closely related and may be separated from other species and each other only with difficulty. McGregor (1941) reported schoenei closest to T. atlanticus McG., and Lienk and Chapman (1951) said that canadensis was morphologically and biologically similar to T. bimaculatus Harvey. Baker and Pritchard (1953) reported that both schoenei and canadensis were similar to T. pacificus McG. and could be separated only by the striae between the inner sacral setae on the female and the characters on the aedeagus of the males.

Tetranychus canadensis was reported as being similar to T. schoenei by Atcheson (1953). Baker and Pritchard (1953) reported that no characters were known to separate the females of the two species and that males must be mounted for an accurate determination.

McGregor and Newcomer (1928) made a cross breeding experiment between Paratetranychus pilosus (Canestrini and Fanzago) and Paratetranychus citri McG. to clear up the taxonomic status between the two by mating experiments. Essig (1922) concluded that the mite found on both deciduous and citrus trees in California was P. pilosus and therefore P. citri was a synonym. Subsequent writers followed Essig's conclusions, in spite of the fact that in 1919 McGregor had described the anatomical differences between the two.

It had already been established that unfertilized females of these species deposit eggs normally and the eggs hatch, but that the resulting mites were always males (Parathenogenesis). If the two were distinct species then only males would be produced from the crossing. In the cross mating of the two, no females resulted and the writers concluded that P. citri and P. pilosus were two distinct species.

In 1950 there was disagreement as to the taxonomic status of Tetranychus multisetis McG. and T. bimaculatus. McGregor in 1950 had described specimens as T. multisetis that had previously been described as T. bimaculatus. Reports on cross mating of the two were made by Keh (1952).

Mites were raised on yellow sorrel plants cut into small sections and kept in vials of water. Tanglefoot was put on the vial top to prevent other mites from getting on the plants. A board with holes drilled at intervals was used to hold the vials, but no contact of foliage of separate cultures was allowed.

Females resulted from the cross mating but there was a decline in their fertility. The experimental results together with a consideration of differences in geographical distribution indicated that T. multisetis is a subspecies of T. bimaculatus (Keh, 1952).

Determination of mites from fruit trees in the Yakima Valley, Washington was made by McGregor in 1950 as Tetranychus bimaculatus or T. pacificus. Baker (1951) determined that the prevalent species in the same area was T. mcdanieli McG. and the change in determination suggested that pacificus and mcdanieli might actually not be distinct species (Newcomer, 1954). In 1953, Newcomer made a series of biological experiments to determine whether or not the two species were distinct.

Newcomer raised the mites in cells made up of recessed oblong pieces of plywood, blotting paper and plexiglass. Holes were drilled in the plywood and the plexiglass was used as a cover for the cell. Apple leaves were used for food and the blotting paper on the bottom of them was kept moistened so that the leaves lasted about one week.

Mating was observed in nine of the 36 crosses made, but in some of the observations the male seemed to have difficulty in mating with the female, which might be expected if they were distinct species.

A few females resulted from the crossing but it was thought that the wrong males could have been put in these cells. It was concluded from these studies that pacificus and mcdanieli are distinct species.

CHEMICAL CONTROL

There have been many materials used to control tetranychid mites, but only a few have been tried on schoenei and canadensis.

Some of the first chemicals used for control of mites were lime-sulfur, lye-sulfur, sulfur, kerosene soap emulsion (Russell, 1908); lubricating oil sprays and potash fish oil soap sprays (Newcomer and Yothers, 1927). Richardson (1935) reported that acetone extracts of derris and sulphonated castor oil provided a control of 93 to 100 percent of T. bimaculatus on tomatoes.

Selocide was suggested as a control of T. pacificus on apple (Moore et al., 1941) and DN 111, a dinitro-o-cyclohexylphenol salt, controlled T. bimaculatus and did no foliage injury to rose, carnation, peach, lima bean, alfalfa, wheat, oat, barley, corn, or sorghum plants (Parker, 1944) and (Alexander et al. 1944).

DN 111 and xanthone was added to DDT sprays to control Paratetranychus pilosus and T. schoenei on apple trees. It did not completely control the mites but kept the populations down to a minimum, (Hough, 1946). Tests of new materials were made in 1947 against the same two species and these were the most effective in the order named: neotran, dioctyl phthalate and parathion. TEPP and HETP were among the less effective materials (Hough, 1948).

Bewick (1947) ran some chemical control tests against T. bimaculatus in Oklahoma on apple and reported that DMC and DN 111 were very effective. Furr (1955) reported collecting bimaculatus only once from apple and the most common species found on it was canadensis followed by schoenei. Due to his findings it is thought by current workers that Bewick's work was done on canadensis or schoenei instead of bimaculatus. This is possible because of the similarity between bimaculatus and canadensis as reported by Lienk and Chapman (1951).

Parathion used as a dust or spray was used against Tetranychus species with results of almost 100 percent kill in 1948 and 1949. (Jones and Rosenstiel, 1948 and Pritchard and Beer, 1949). Parathion and aramite gave excellent control of T. bimaculatus and T. pacificus (Morgan and Downing, 1950).

In 1952 chemical tests for the control of T. bimaculatus and Septanychus texazona McG. were made on cotton. Approximately 0.4 pounds per acre of aramite gave control of mites in the field comparable to that of two pounds of ovotran, R-242, genite-923 and 15 pounds sulfur dust. Parathion, TEPP and EPN gave effective control at about 0.25 pounds per acre (Gaines et al. 1952).

Resistance to parathion has developed in some mites and good control of these has been obtained by combining parathion with DMC or by using malathion, EPN, systox, aramite, R-242, ovotran (Newcomer and Dean, 1953).

Demeton and Geigy 337, 358, 359 and 367 provided a good control of orchard mites up tp 17 days after they were applied (Lienk and Chapman, 1953).

Ebeling and Pence (1954) reported that LD 50's for 16 acaricides had been determined against the eggs, larvae and adults of T. bimaculatus. The larvae were more susceptible to neotran, ovotran, genite-923, karathane, DN 111 and DN 289, while the adults were more susceptible to aramite, parathion, malathion, EPN, diazinon and demeton. Neotran, ovotran and genite-923 caused lower LD 50's against the eggs than the adults. The egg stage was the most resistant to all other chemicals and took an average of 37.7 times more toxicant to effect a kill than did the adults.

Cole and Fisk (1955) used the following system of comparing the toxicity of acaricides in the laboratory. They used red kidney bean plants and to make a smaller area of each leaf, a pair of leather punching pliers was designed to cut a 1 1/2 inch circle without severing the leaf from the plant.

Four to eight single leaf replicated were used for each concentration of chemical tested. The percent mortality was computed on the basis of the total number of mites for each concentration, rather than by averaging individual replicates. They obtained better results by spraying than by the dipping method with the same acaricides.

METHODS AND MATERIALS

In the fall of 1954, a population of T. canadensis was collected from elms and a population of T. schoenei from roses which were found on the Oklahoma A. & M. campus.

BIOLOGICAL STUDIES:

Sweet potato plants were acquired from hot beds on the campus and the mites transferred to them. They proved to be good hosts for both species and were used as such throughout these studies.

Rearing Methods - Sweet potato leaves for rearing the mites were cut from the plant with a small section of the runner and put into vials of water, where they rooted at the base of the leaf stem and would stay green from four to six weeks. Sweet potatoes were placed in water for the production of fresh plants as needed.

Sweet potato leaves for rearing mites were placed in vials secured in holes in 1 x 12 inch boards spaced so that the leaves did not touch.

A suggested method of rearing the mites within vaseline rings on the under side of the leaf was tried, but was not satisfactory. After several other methods failed, successful plexiglass rearing cages were made 2 1/2 x 2 1/2 x 1/4 inches in dimensions. For life history studies, two beveled oblong holes were made near the center of each about 1/4 x 3/4 inches in diameter and about 1/8 of an inch apart end to end. Only one hole was made in each for the breeding tests and these were about 1 1/4 x 3/8 inches in diameter and centered in the plexiglass piece. Plain glass slides were used as covers for the cages. A piece of gauze was placed between the leaf and the slide to prevent injury to the leaf. Large spring clips were used to hold the cages together.

The cages had to lie flat, so cotton was used to plug the vials holding the leaves and a 1 x 4 x 7 inch board was used to hold each cage. This way the board, cage and all could be slipped under the binocular microscope for the observance of mites through the glass slide on top.

A record was kept by means of a thermograph for part of the life history studies that were made at variable temperatures. Part of the life history studies and all of the mating experiments were run in a constant temperature cabinet that was kept at 80±.5°F. The water in the vials had to be replenished every third day in the temperature cabinet and every other day outside of it.

Moving and checking methods - During the life history studies females were moved from one cage to another when they had deposited from two to four eggs in them. This was done so a record of each period and stage of each mite could be kept. A new generation was started with the first pair of mites that developed in the old generation. The mites were moved with a soft camel's hair brush to keep from injuring them.

Young females in the deutonymph stage or young adult females that had developed in cages by themselves were used in the mating experiments. In order to obtain rapid mating, males used in the mating tests were isolated until placed in the cage with a female. Three to five males were put in with each female and in three to four days the remaining males were checked for species identification. The male progeny were checked to make sure they were the same species as the female. Two cages, in most cases were enough to raise the progeny of one female.

Every mite and egg was checked twice a day in the life history studies and once every other day in the mating experiments.

ACARICIDE TESTS

The 1 x 12 x 20 inch boards with the ten holes drilled in each were

used to hold the vials and leaves in the acaricide tests. One sweet potato leaf was put in each vial and each one counted as a replicate. Ten mites were put on each leaf and ten replicates used for each concentration, which made a total of 100 mites in each test.

Materials - formulations - There were 20 materials used in the acaricide tests and Table 1 is a list of the materials with the name of the company who furnished them. Most of these are new materials and were tested to see if any showed promise as an acaricide. The best one was compared in the laboratory with two other acaricides to see how long the residual effects lasted on schoenei and canadensis. As acetone was used as the solvent in all cases, a test was made with a 0.1 percent concentration to make sure it would not affect the mites. It had no effect on them so a 1.0 percent acetone solution was made of all materials before the tests were started. Aramite and Hercules Powder 528 were 25 percent emulsifiable concentrates; Parathion was a 5.0 percent emulsifiable concentrate, all the other solutions were made from technical materials. The test materials made from these base solutions were a 0.1, 0.075, 0.050, 0.025, 0.010 and 0.005 percent concentrations. Triton x-100 (Polyethylene glycol ethers), was added in making the water emulsions to insure an even spread of the material on the leaves. The materials were mixed and applied to the leaves in another building away from where the experiments were run.

Application methods - The dipping method was used for applying the emulsions to the leaves. As soon as they were dry a ring of vaseline was applied around the stem at the base of the leaf to keep the mites from wandering and then mites were put on them. The mites were transferred from the populations by lightly moving the end of a camel's hair

Table 1. Common name, chemical name and source of acaricides referred to in this paper.

Source of Material	Common Name	Chemical Name
Phillips Pet. Co.*	101	2-Hydroxyethyl n-octyl sulfide
"	102	2-Hydroxyethyl tert-octyl sulfide
"	103	2-Hydroxyethyl tert-nonyl sulfide
"	104	2-Hydroxyethyl n-decyl sulfide
"	105	2-Hydroxethyl tert-dodecyl sulfide
"	106	2-Hydroxyethyl phenylethyl sulfide
"	107	Tert-butyl thiosulfenyl morpholine
"	108	Diphenylethyl disulfide
"	109	A Dithiocarbamate
"	110	Butadiene furfural copolymer
"	111	Glycol bis(mercapto acetate)
"	112	1,3-Bis(chloroacetoxy) propane
"	113	1,2,6-Tris(chloracetoxy) hexane
"	114	2-Hydroxypropyl tert-dodecyl sulfide
Dow Chemical	14**	
"	15	
Hercules Powder Co.	528	
Commercial Product	Aramite	2(p-tert-butylphenoxy)isopropyl 2-chloroethyl sulfide
"	Parathion	o,o-Diethyl-o-p-nitrophenyl thiophosphate
"	Acetone	2-propanone
J. R. Geigy, A. G.	DDT	Dichloro diphenyl trichloroethane
"	Diazinon	Isopropylmethylpyrimidyl diethyl thiophosphate
Sherwin-Williams Co.	DMC	Di (p-chlorophenyl) ethanol
Dow Chemical	DN 111	Dicyclohexylammonium dinitro-o-cyclohexylphenate
"	DN 289	2-(1-methyl-n-propyl)-4:6-dinitrophenol
E. I. DuPont & Co.	EPN	Ethyl p-nitrophenyl benzenethiophosphonate
Calif. Spray Chem. Corp.	HETP	Tetraethyl pyrophosphate
"	TEPP	Tetraethyl pyrophosphate
American Cyanamid Co.	Malathion	S-(1:2-dicarbethoxyethyl)-o.o-dimethyl phosphorodithioate
Dow Chemical	Neotran	Bis(p-chlorophenoxy)methane
"	Ovotran	p-chlorophenyl p-chlorobenzenesulphonate
Stauffer Chem. Co.	R-242	p-chlorophenyl phenyl sulphone

Table 1. (Continued)

Source of Material	Common Name	Chemical Name
Chemegro Corp.	Systox	Ethyl mercaptoethyl diethyl thiophosphate
General Chem. Co.	Genite-923	2,4-Dichlorophenyl ester of benzenesulphonic acid
Rohm & Haas Co.	Karathane	Dinitrocaprylphenyl crotonate
E. I. DuPont Co.	Selocide	$(KNH_4S)_5Se$
"	Xanthone	Diphenylene ketone oxide

*Code number used for Phillips products for the convenience of writer.

**New materials, chemical names not available.

brush across the surface of an infested leaf thus picking up the mites on the brush and then laying it down on the treated leaf and counting the number of mites that crawled off. A clean brush was used for each material to keep the mites from getting any of the test materials except that on the treated leaf to which they were transferred. The mites did not wander around too much and about one out of 100 got in the vaseline around the leaf stem.

Checking methods - The mortality tests were made at a 0.1 percent concentration of each material. The tests were checked at 4, 24, and 48 hours because it was figured if they didn't produce high mortality the first 24 hours or a good residual action the next 24, that they showed little promise as a mite control. Aramite was used as a comparison for the results of the new materials.

Three materials, HP-528, aramite and parathion were used in the residual experiments. The replicates were checked at 4 hours and 24 hours the first time, and if an LD 99 or an LD 50 were obtained, the live mites, if any, were removed and 10 mites from the untreated populations were put on each replicate and checked in 24 hours. This was repeated until the results were below an LD 50 checked after a subsequent 24 hour period. This set of replicates was then discarded. These tests were made on the three materials at a 0.075, 0.050, 0.025, 0.010 and a 0.005 percent concentration.

The checks were the same size as the tests, 10 replicates or 100 mites to each check. A new set of check replicates was started every 6 to 9 days according to how fast the mites reproduced on the old check.

The sweet potato plants grown in water apparently were not as vigorous as those that grow normally in the soil and were more adversely af-

fected by the test materials. If some of the leaves in a set of replicates had to be discarded and the residual effects were still providing an LD 50 or more, the test was continued until only two replicates were left for that concentration, but in most cases enough stayed green to complete the experiment.

The replicates were checked by eye for live mites, but if any doubt existed they were checked under a stereoscopic microscope. It was not difficult to tell the live mites from the dead ones, because the dead mites turned a different color and the live ones started crawling when disturbed. Strict accounting of the number of mites originally placed on each leaf was not always possible. Those missing were presumed to have died and fallen off the leaf although as a general rule there was enough webbing present to prevent disappearance.

A record of the temperature was kept with a thermograph during the acaricide experiments. The treated and check replicates were kept in the same room and under the same conditions.

Tetranychus schoenei was used mostly in these tests, but both T. schoenei and T. canadensis were used in testing the 0.025 and 0.010 percent concentrations of the three materials in the residual experiments.

RESEARCH RESULTS

LIFE HISTORY STUDIES

The biological data presented here for T. schoenei and T. canadensis are based on the rearing of four generations of each under constant temperature (80°F.) conditions and on two generations at room temperature. Both were kept going the same length of time, but outside the cabinet the temperature was lower and variable so incubation and development took longer.

The adult females spin a considerable amount of silk webbing that is worked into a net-like pattern over the leaf. The deutonymphs spin a similar webbing but not as much as the adults. This web aids egg attachment, attachment of tarsal claws preceding the act of molting and provides a more convenient method of travel.

These two species of mites as in all cases of members of the family, Tetranychidae, deposit eggs from which hatch six-legged larvae. The larvae transform into eight-legged protonymphs, which in turn become deutonymphs and finally adults.

Each stage of development is divided into an active feeding period and a quiescent period after which it molts. The period of quiescence is devoted to the formation of new parts and to necessary physiological processes prior to the actual molting. Before the mite becomes quiescent, it attaches itself by means of its tarsal claws to the webbing or the leaf surface. When it is ready to molt, the old skin splits transversely across the cephalothorax and the mite backs out of the cephalic half of the old skin and then crawls out of the caudal half, it then rests and feeds until it is strong enough to travel about.

Tetranychus schoenei McG. - The length of a generation was counted from the day the first egg was laid until the last mite died or was lost. A generation lasted 38.2 days at a constant temperature of 80°F. and 51.6 days at temperatures varying from 55° to 70°F. and averaging 60.7°F., a variation of 13 days.

The incubation period of the eggs varied with the temperature as shown in Table 2. The time varied from three days at a constant temperature of 80°F. to seven days at an average temperature of 58.7°F. with it varying from 49° to 69°F.

The development times are given as maximum and minimum periods and stages.. The periods are feeding and quiescence and the stages; larvae, protonymph and deutonymph. The data shown in Table 3 were obtained at an average temperature of 80°F. The maximum figures are in Table 4 and the average temperature was 63.1°F. with it varying between 49°and 72°F.

The maximum of each period was figured as the longest time a mite was in that period and the minimum as the shortest time. The average was figured according to the number of mites and how long each was in that period. The total averages were figured by adding the two periods together and the combined total is the result of all stages, larva, protonymph and deutonymph added together and using the maximum and minimum time it took several mites to go through the whole development stage as a guide.

The duration of the larval stage ranged from a minimum of 1.5 days for males and 1.7 days for females to a maximum of 3.6 days for males and 4 days for females as shown in Tables 3 and 4. The average for the two sexes ranged from 1.6 to 3.9 days.

Table 2. Incubation of T. schoenei eggs at different temperatures.

No. of Eggs	Temperature Average	Temperature Variation	No. of Days Incubation
42	80°F.	79.5°-80.5°F.	3
23	67.5°F.	60° -78°F.	5
27	58.7°F.	49° -69°F.	7

Table 3. Days required for developmental periods and stages of T. schoenei males and females at a temperature of 80±.5°F.

		Feeding			Quiescent			Total		
Sex	No.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.
LARVA										
Male	15	1	1	1	.5	.5	.5	1.5	1.5	1.5
Female	15	1	1	1	1	.5	.7	2	1.5	1.7
Both sexes	30	1	1	1	1	.5	.6	2	1.5	1.6
PROTONYMPH										
Male	15	1	.5	.6	1	.5	.6	2	1.0	1.2
Female	15	1	.5	.7	1	.5	.7	2	1.0	1.4
Both sexes	30	1	.5	.7	1	.5	.7	2	1.0	1.4
DEUTONYMPH										
Male	15	.5	.5	.5	.5	.5	.5	1	1.0	1.0
Female	15	.5	.5	.5	.5	.5	.5	1	1.0	1.0
Both sexes	30	.5	.5	.5	.5	.5	.5	1	1.0	1.0
COMBINED TOTAL										
Male	15							4.5	3.0	3.7
Female	15							5.0	3.0	4.0
Both sexes	30							4.7	3.0	3.8

Table 4. Days required for developmental periods and stages of T. schoenei at varying temperatures from 49° to 72°F. and an average of 63.1°F.

		Feeding			Quiescent			Total Days		
Sex	No.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.
LARVA										
Male	9	2.5	2	2.3	1.5	1.0	1.4	4	3.0	3.6
Female	9	3.0	2	2.5	2.0	1.5	1.6	5	3.5	4.0
Both sexes	18	3.0	2	2.4	2.0	1.5	1.5	5	3.5	3.9
PROTONYMPH										
Male	9	1.5	1	1.4	1.5	1.0	1.3	3	2.0	2.7
Female	9	2.0	1	1.5	2.0	1.0	1.5	4	2.0	3.0
Both sexes	18	2.0	1	1.5	2.0	1.0	1.4	4	2.0	2.9
DEUTONYMPH										
Male	9	1.5	1	1.2	1.5	1.0	1.2	3	2.0	2.4
Female	9	1.5	1	1.3	1.5	1.0	1.3	3	2.0	2.5
Both sexes	18	1.5	1	1.3	1.5	1.0	1.2	3	2.0	2.4
COMBINED TOTAL										
Male	9							9	7.0	8.7
Female	9							12	7.5	9.5
Both sexes	18							12	7.5	9.1

The minimum for the protonymph stage was 1.2 days for males and 1.4 days for females and the maximum was 2.7 days for males and three days for females. The average for the two sexes ranged from 1.4 to 2.9 days.

The deutonymph stage lasted a minimum of one day for both sexes. The maximum length of time was 2.4 days for the male and 2.5 days for the female with an average of 2.4 days for both sexes.

The minimum time required for development from egg to adult was four days for the female and 3.7 days for the male and the average of both sexes was 3.8 days. The maximum time of development was 8.7 days for the male and 9.5 days for the female with the average of both sexes being 9.1 days.

The preoviposition period ranged from 1.5 days at an average temperature of 80°F. to 3.5 days at an average temperature of 62.7°F.

The maximum average life span for the female was 16.6 days and for the male 12.8 days at an average temperature of 63°F. as shown in Table 5. The females averaged ovipositing 3.9 eggs per day and a total of 66.5 during their life. The average minimum life span was 14.8 days for females and 11.5 days for males at an average temperature of 80°F. The females oviposited 4.5 eggs per day with a total of 67.3 eggs per female. The longest a female lived was 22 days and the most eggs any female oviposited was 85. The mating time ranged from four to five minutes.

Tetranychus canadensis McG. - A generation of T. canadensis varied from a minimum of 42.4 days at 80°F. to 56 days at an average temperature of 60.7°F. and varying from 55° to 70°F. A generation was figured as starting the day the first egg was laid until the last mite died or was lost.

Table 5. Average life span of T. schoenei males and females and number of eggs oviposited.

Sex and No.	Temperature		Ave. Adult Life Days	Eggs	
	Average	Variation		Ave. per Day	Ave. per Female
F. 6	80°F.	79.5-80.5°F.	14.8	4.5	67.3
F. 7	63°F.	50 -76°F.	16.6	3.9	66.5
M. 12	80°F.	79.5-80.5°F.	11.5		
M. 10	63°F.	50 -76°F.	12.8		

The incubation period varied from a minimum of three days at 80°F. to a maximum of eight days at an average temperature of 58.6°F. and varying from 49 to 69°F. as shown in Table 6.

Table 6. Incubation period of T. canadensis eggs at different temperatures.

No. of Eggs	Temperature		No. of Days Incubation
	Average	Variation	
42	80°F.	79.5-80.5°F.	3
23	67.5°F.	60 -78°F.	5
27	58.7°F.	49 -69°F.	7

The minimum periods and stages of development are shown in Table 7 and the temperature during this time was 80°F. The maximum periods are shown in Table 8. The average temperature was 63.7°F. and it varied from 49 to 72°F.

The minimum, maximum, and average periods and stages shown in Tables 7 and 8 were worked out in the same manner as those for T. schoenei in Tables 2 and 3 and explained on page 18.

Table 7. Days required for developmental periods and stages of T. canadensis at a temperature of 80±.5°F.

		Feeding			Quiescent			Total		
Sex	No.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.
LARVA										
Male	15	1	.5	.7	1	.5	.6	2	1	1.3
Female	15	1	.5	.9	1	.5	.8	2	1	1.7
Both sexes	30	1	1.0	.8	1	.5	.7	2	1	1.5
PROTONYMPH										
Male	15	1	.5	.7	.5	.5	.5	1.5	1	1.2
Female	15	1	.5	.7	.5	.5	.5	1.5	1	1.2
Both sexes	30	1	.5	.7	.5	.5	.5	1.5	1	1.2
DEUTONYMPH										
Male	15	.5	.5	.5	.5	.5	.5	1.0	1	1.0
Female	15	1.0	.5	.6	.5	.5	.5	1.5	1	1.1
Both sexes	30	1.0	.5	.6	.5	.5	.5	1.5	1	1.1
COMBINED TOTAL										
Male	15							4.5	3	3.6
Female	15							5.0	3	4.0
Both sexes	30							4.7	3	3.8

Table 8. Days required for developmental periods and stages of T. canadensis at an average temperature of 63.7°F. and varying between 49 and 72°F.

		Feeding			Quiescent			Total Days		
Sex	No.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.
LARVA										
Male	6	2.5	2	2.4	1.5	1.0	1.3	4.0	3	3.7
Female	8	3.0	2	2.8	1.5	1.0	1.4	4.5	3	4.1
Both sexes	14	3.0	2	2.6	1.5	1.0	1.3	4.5	3	3.9
PROTONYMPH										
Male	6	1.5	1	1.4	+1	-1.0	1.0	2.5	2	2.4
Female	8	1.5	1	1.4	1.5	1.0	1.1	3.0	2	2.5
Both sexes	14	1.5	1	1.4	1.5	1.0	1.1	3.0	2	2.4
DEUTONYMPH										
Male	6	1.5	1.0	1.4	1.5	1.0	1.4	3.0	2	2.8
Female	8	2.0	1.5	1.6	2.0	1.5	1.6	4.0	3	3.1
Both sexes	14	2.0	1.5	1.5	2.0	1.5	1.5	4.0	3	2.6
COMBINED TOTAL										
Male	6							9.5	7	8.9
Female	8							11.0	8	9.7
Both sexes	16							10.0	8	9.3

The duration of the larval stage ranged from a minimum of 1.3 days for males and 1.7 days for females (Table 7) to 3.7 days for males and 4.1 days for females as a maximum (Table 8). The average of both sexes was a minimum of 1.5 days to a maximum of 3.9 days.

The minimum of the protonymph stage was 1.2 days for both sexes. The maximum was 2.4 days for males and 2.5 days for females and the average for both sexes was 2.4 days.

The deutonymph stage took a minimum of one day for the male and 1.1 days for the female with an average of 1.1 days for both sexes. The maximum period was 2.8 days for the male; 3.1 days for the female and an average of 2.6 days for both sexes.

The minimum time required for development from egg to adult was 3.6 days for the male; four days for the female and an average of 3.8 days for both sexes. The maximum time was 8.9 days for the male and 9.7 days for the female. The average of both sexes was 9.3 days.

The preoviposition period ranged from 1.5 days at a temperature of 80°F. to 3.5 days at an average temperature of 62.7°F.

The maximum average span of life for the females was 18.1 days at 63°F. temperature and 14.7 days for the males (Table 9). The females oviposited an average of 3.9 eggs per day with a total average of 71.2 eggs per female. The minimum life span was an average of 16.4 days for the females and 13.8 days for the males at a temperature of 80°F. The average number of eggs deposited per female was 4.5 eggs per day and the total was 73.9 eggs per female. The longest life of any female was 22 days and the most eggs oviposited by any one female was 122. The mating time was from four to five minutes.

Table 9. Average life span of T. canadensis males and females and number of eggs oviposited.

Sex and No.	Temperature		Average Days Length of Life	Eggs	
	Average	Variation		Ave. per Day	Ave. per Female
F. 12	80°F.	1°F.	16.4	4.5	73.9
F. 8	63°F.	50-76°F.	18.1	3.9	71.2
M. 17	80°F.	1°F.	13.8		
M. 13	-	-	14.7		

MATING TESTS

There has been much speculation as to whether T. schoenei and T. canadensis are distinct species, subspecies or even the same species. It has already been reported in the literature review (Baker et al. 1953) that the females cannot be told apart and males must be mounted to make an accurate determination. The figures in the life history studies are so close that they could be a subspecies or even the same species. To clear up this controversy reciprocal mating tests were made between the two species in March, April and May of 1955.

These experiments are based on the well-known fact that infertile eggs will hatch but produce only males and that males of one species of mite may mate with the female of another species but the eggs are not fertilized and so the progeny will be all males. This method has been used successfully by McGregor and Newcomer (1928) and Newcomer (1954) in determining the taxonomic status of other species of mites.

The results of the reciprocal matings are given in Tables 10 and 11. Attempted mating was observed in 23 of the 41 crosses made and it was probably attempted in all of them. In all the observations the males had difficulty mating with the females which might be expected if the species

are distinct. Newcomer (1954) also found this true in his mite mating experiments. The canadensis male with the small knob on the aedeagus had difficulty mating with the schoenei female when the male of her own species has a knob on the aedeagus 1 1/2 to 2 times as large as the canadensis male. It may be that actual copulation did not take place in any of these attempted crossings, although three to four males were observed to attempt mating one right after the other.

The adult progeny from all of these crossings, both schoenei x canadensis and canadensis x schoenei, were males (Tables 10 and 11). A record was not kept of the percentage of eggs that hatched but most of them were viable to adulthood. Of the eggs deposited, 84.9 and 82.3 percent, respectively, produced males.

There were no females produced and with the difficulty observed in mating, it is concluded from these studies that schoenei and canadensis are distinct species even though they are morphologically and biologically similar.

ACARICIDE TESTS

Tests of new materials and of some already used as acaricides were made from May to June of 1955 on the mites Tetranychus schoenei and T. canadensis. These tests were made to see if the new materials showed any promise as a mite control. Tests were run on the best ones with other acaricide materials to compare the life of their residual effects. Some ovicidal records were kept while running these tests.

Mortality tests - Table 12 shows the materials and percent mortality at a 0.1 percent concentration. Of the new materials HP 528 gave 100 percent mortality and was used in later tests. The Phillips Petroleum Company materials 104 and 109 got more than a 50 percent mortality

Table 10. Results of mating male T. schoenei with female T. canadensis mites.

Date of Mating	Length of Life of Female	Eggs Deposited	No. Progeny Maturing		Percent Eggs Producing Males
			Male	Female	
March 25	7*days	7	7	0	100
28	10*	28	28	0	100
April 4	14*	35	31	0	88.5
	16 & 19	116	103	0	88.7
	13*	33	30	0	93.6
April 14	14	44	40	0	90.9
	9*	27	25	0	92.1
	17	62	54	0	87.1
April 27	14*	47	39	0	82.9
	15*	53	47	0	88.6
	15*	57	46	0	80.7
April 28	8*	20	20	0	100
	8	26	23	0	88.4
	10	37	30	0	81.4
	14	46	31	0	67.4
May 2	12	31	21	0	67.7
May 5	9*	27	26	0	96.3
	6*	12	12	0	100
	11	39	34	0	87.1
	14	44	34	0	77.2
May 7	12*	38	29	0	76.2
	9	24	20	0	83.3
	10	23	14	0	60.8
Total or average		876	744	0	84.9

*Attempted mating observed.

Table 11. Results of mating male *T. canadensis* with female *T. schoenei* mites.

Date of Mating	Length of Life of Female	Eggs Deposited	No. Progeny Maturing		Percent Eggs Producing Males
			Male	Female	
March 25	10*days	38	35	0	92.1
	14*	56	49	0	87.5
	13*	49	44	0	89.8
March 31	9	28	28	0	100
	11*	38	35	0	92.1
	12	43	39	0	90.7
	9	30	19	0	63.3
April 7	12	39	36	0	92.3
April 11	7*	20	20	0	100
	6	19	16	0	84.2
	8*	19	19	0	100
	8	30	27	0	90.0
April 15	13	45	34	0	75.5
	9	26	11	0	42.3
April 24	16*	58	45	0	77.6
	14	49	40	0	81.6
	15	47	43	0	91.4
May 2	11*	29	29	0	100
	17*	58	33	0	56.9
	15	57	49	0	85.9
	7	24	20	0	83.3
May 3	16*	55	44	0	80.0
	17	64	47	0	73.4
	17*	65	59	0	91.6
	13*	45	37	0	82.2
	13	48	33	0	68.7
	14	59	46	0	77.9
Total or average		1138	937	0	82.3

*Attempted mating observed.

Table 12. Percentage mortality of T. schoenei exposed to 0.1 percent concentrations of acaricides.

Code No.* or Name	Temperature	Percent Mortality** 24 hours	Date Tested
101	54°F.	13%	3-22-'55
102		7	
103		43	
104		70	
105		45	
106		8	
107	76°F.	12	4-4-'55
108		3	
109		72	
110		1	
111		17	
112		36	
113		9	
114		4	
Dow 14		31	
Dow 15		21	
H.P. 528		100	
Aramite	54°F.	100	3-22-'55
Acetone		6	

*For chemical name refer back to Table 1, Page 12.

**Check had 5% mortality.

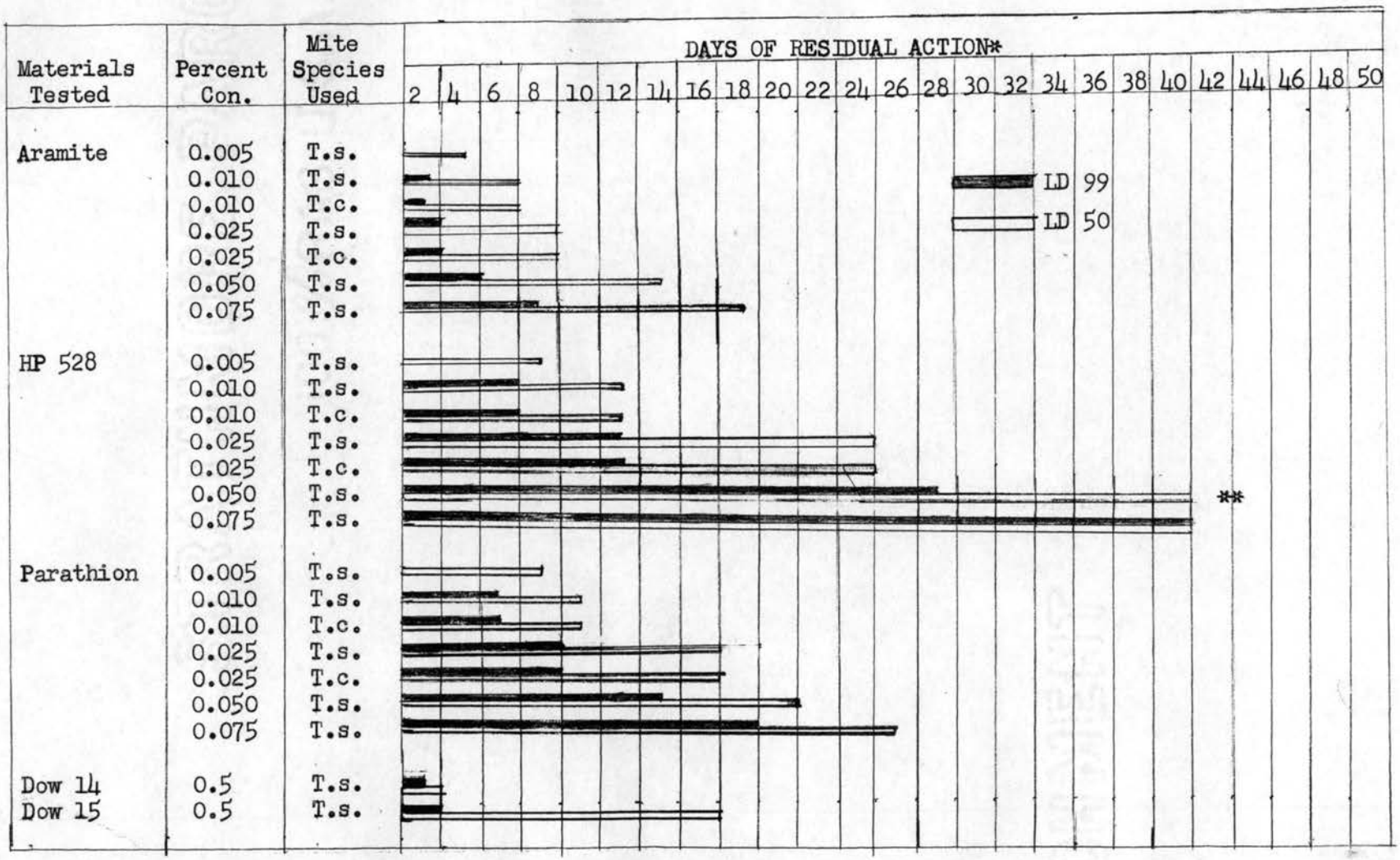
in 24 hours, but subsequent control was not evident and they showed no ovicidal control at all. Since acetone was used as a dilutent to prepare the base solutions, checks using this compound were run concurrently with the untreated checks. No significant variation in mortality was observed between the two types of checks. Aramite is a known acaricide and was used as a comparison against the results of the new materials. Dow 14 and 15 showed poor results, but were carried over into the residual tests and tried at 0.5 percent to see what the effects would be at a higher concentration. Parathion was not used in the mortality tests, but it is a known acaricide and was used in the later test.

The chemical materials used in this test were phytotoxic to some extent, but the test was not run long enough to see what the end results would be.

Residual tests - Results of the residual experiments are given in Figure 1. An LD 99 as used here means that 99 percent of the mites in the replicates for one concentration died in 24 hours. The Dow Chemical Company materials showed a little better results at a concentration of 0.5 percent with number 15 being the best. It gave an LD 99 for two days and an LD 50 for 16 days, but showed no ovicidal effects.

Results on the other three materials show that HP 528 was the best, parathion next and aramite last. None of the three gave an LD 99 at the 0.005 percent concentration, but HP 528 and parathion gave an LD 50 for seven days and aramite for three days. At a concentration of 0.010 percent, HP 528 gave an LD 99 for six days and an LD 50 for 11 days as compared to an LD 99 for 5 and 1 and an LD 50 for 10 and 6 days for parathion and aramite respectively. Tests were run at this concentration with both T. schoenei and T. canadensis and the results showed no difference between the species.

Figure 1. Residual toxicity of acaricides used at varying concentrations on T. schoenei and T. canadensis.



*Dates tests started and temperatures during test in Table 13.

**Tests discontinued because replicate leaves died.

The results at a 0.025 percent concentration showed an LD 99 for 11, 8, and 2 days; an LD 50 for 24, 16, and 8 days for HP 528, parathion and aramite respectively. Tests were run at this concentration using both species of mites and there was no difference in the time of residual effects on them.

There was a large division between the three materials at the 0.050 and 0.075 percent concentration level. At the lowest concentration HP 528 got an LD 99 for 27 days, parathion for about half that time, 14 days and aramite for only four days. Most of the plant leaves used in this test were dead at 40 days but HP 528 was still getting an LD 50 at a 0.050 percent concentration. Parathion got an LD 50 for 20 days and aramite for 13 days at the same concentration.

Hercules Powder 528 at a 0.075 percent concentration was still getting an LD 99 at 40 days when the plant replicates died out. At this same concentration parathion got an LD 99 for 18 days and aramite for only seven days. They got an LD 50 of 25 and 17 days respectively.

These three materials showed no ovicidal action at any concentration, although as long as the LD 99 lasted the young were dead soon after hatching.

In Table 13 is the information as to the date each test was started, average temperatures during the test and the number of leaves in each test affected by the phytotoxicity of each material and concentration. The temperature varied between tests on different concentrations about 10°F., but each test at the same concentration of each material, except Dow 14 and 15 were started at the same temperature.

Table 13. Phytotoxicity of acaricides to sweet potato leaves at different concentrations.

Material	Concentration	Date Test Started	Days Test Lasted	Average Temperature During Test	No. of Leaves Affected at End of Test
Aramite	0.005	5-18-55	3	66.6°	0
	0.010	5- 4-55	6	76.1	2
	0.010	5- 4-55	6	76.1	2
	0.025	4-25-55	8	73.2	3
	0.025		8	73.2	3
	0.050		13	72.8	4
	0.075		17	72.4	4
HP 528	0.005	5-18-55	7	67.9	3
	0.010	5- 4-55	11	72.0	3
	0.010	5- 4-55	11	72.0	3
	0.025	4-25-55	24	71.0	2
	0.025		24	71.0	2
	0.050		40	73.5	9
	0.075		40	73.5	9
Parathion	0.005	5-18-55	7	67.9	1
	0.010	5- 4-55	10	72.4	4
	0.010	5- 4-55	10	72.4	4
	0.025	4-25-55	16	72.5	5
	0.025		16	72.5	5
	0.050		20	71.5	7
	0.075		25	70.8	8
Dow 14	0.5	5-18-55	2	68.2	3
Dow 15	0.5	5-18-55	16	70.6	5

The amount of phytotoxicity shown in these tests is not conclusive because each test was run a different number of days and three or four kinds of sweet potatoes were used. More phytotoxicity tests should be made before recommending these materials for use on tender plants.

These tests show that HP 528 had the longest residual effects at all concentrations, the fastest killing power and the least toxic effect on the test plants.

DISCUSSION

The life history studies show that Tetranychus schoenei and T. canadensis are very similar. At a temperature of 80°F. it took the eggs of both species the same length of time to hatch (three days), but at a lower temperature it took T. canadensis eggs eight days to hatch and T. schoenei eggs only seven days.

Table 14 is a comparison of the number of days required to develop from egg to adult for both species. They are the same at a constant temperature, but at the lower variable temperatures, it took both male and female canadensis 0.2 of a day longer than schoenei.

Table 15 is a comparison of the average life of both male and female of both species and the eggs laid by each. It can be seen that T. canadensis females live an average of almost two days longer than do female T. schoenei. The T. canadensis males live an average of over two days longer than the T. schoenei males. The average eggs per day using more than one female in each group was the same for both species; 4.5 eggs per day at 80°F. temperature and 3.9 eggs per day at an average temperature of 63°F.

Table 14. Comparison of developmental time from egg to adult between T. schoenei and T. canadensis.

Species	Temperature Average	No. of Days Egg to Adult		
		Male	Female	Both Sexes
schoenei	80°F.	3.7	4	3.8
canadensis	80	3.6	4	3.8
schoenei	61.3	8.7	9.5	9.1
canadensis	63.1	8.9	9.7	9.3

Table 15. Comparison between T. schoenei and T. canadensis in average life span and number of eggs oviposited.

Species	Temperature Average	Average Length of Life Days Male	Female	Eggs Average Per Day	Average Per Female
schoenei	80°F.	11.5	14.8	4.5	67.3
canadensis	80	13.8	16.4	4.5	73.9
schoenei	63	12.2	16.6	3.9	66.5
canadensis	63	14.7	18.1	3.9	71.2

A generation of canadensis lasted about four days longer than schoenei at both temperatures. At 80°F. a generation of canadensis averaged 42.4 days and schoenei 38.2 days. A generation of canadensis lasted 56 days and that of T. schoenei 51.6 days at an average temperature of 60.7°F.

The life history studies on T. schoenei coincide with Cagle's (1943) studies on the same species to some extent. He reported the incubation period as three days at 81.6°F. and these studies show the same for a temperature of 80°F. The lowest temperature was 52.6°F. for Cagle's work and incubation took 25 days while these studies showed only seven days at 58.7°F.

The developmental time from hatching to adult was five days at 80.7°F. for Cagle's studies and four days at 80°F. in these, which is a difference of one day at about the same temperature. He reported it took 34 days at an average temperature of 51.0°F. and these studies show it took only 9.5 days at an average temperature of 63.1°F.

The preoviposition period observed by Cagle varied from one to five days while these studies showed the period to be from 1 to 3.5 days.

He reported a generation as lasting from 50 to 65 days, while this work showed it much lower running from 38 to 51 days. The average number of eggs per female in his report was 36 and 37, and these studies showed an average from 66 to 67.

There are many things that could have caused the difference between Cagle's studies and the studies made here. There could be a geographical difference within the species because he made his studies in Virginia and these were made in Oklahoma. There could also be a difference by how often everything was checked. Everything done in this problem was checked twice each day and from his report he may have checked his only once a day. There could be some difference because of the host plants used. He used apple foliage which is their normal host in Virginia, and sweet potato was used as the host plant here.

There is a difference in the results of Cagle's work and that done here, but a life history study of schoenei was not made to confirm Cagle's conclusions, but as a comparison to the life history of canadensis, because they are morphologically similar and many thought they were not distinct species.

The mating experiment proved that T. schoenei and T. canadensis are distinct species. Only young males and females were used and when put together, they attempted mating in only a short time. Attempted mating was observed many times and it may be that there is a morphological difference so that there was no real copulation when cross breeding these two species.

The acaricide tests proved out an unknown material as a good control on these two species of mites. Some of the other experimental materials got a fair mortality, but were not nearly equal to those

such as HP 528 and aramite.

Hercules Powder 528 had the best residual action and during all of its effective time it had a fast killing effect. The other materials, aramite and parathion gave a good kill the second 24 hours, but that still was not enough to equal what HP 528 killed in the first 24 hours.

SUMMARY

The mites T. schoenei and T. canadensis are becoming more of a problem in Oklahoma. They feed on such plants as cotton, apple, pecan, and plum. Those species are similar both morphologically and biologically.

A generation of schoenei lasted from 38.2 days to 51.6 days and the incubation period ranged from three to seven days. The larval stage for an average of both sexes took from 1.6 days to 3.8 days; the protonymph stage from 1.4 days to 3.0 days and the deutonymph stage from 1 to 2.4 days. The total developmental time was from 3.8 to 9.1 days.

Life span of the male was 11.5 to 12.8 days and 14.8 to 16.6 days for the female. The preoviposition period was from 1 to 3.5 days and the average number eggs oviposited per female was from 66.6 to 67.3.

The generations of canadensis lasted from 42.4 days to 56 days and the incubation period ranged from three to eight days.

The larval stage for an average of both sexes took from 1.5 to 3.9 days; the protonymph stage from 1.2 to 2.4 days and the deutonymph stage from 1.1 to 2.6 days. The total development time was from 3.8 to 9.3 days.

Life span of the male was 13.8 to 14.7 days and 16.4 to 18.1 days for the female. The preoviposition period ranged from 1 to 3.5 days and the average number of eggs oviposited per female was from 71.2 to 73.9.

There were 41 reciprocal mating tests made and attempted mating was observed in 23 of them. Difficulty was observed in mating which could be expected if they are distinct species. There were 2,014 eggs depos-

ited and 1,681 maturing progeny, which were all males, proving that these are two distinct species.

A series of new acaricides was tested for their control effects on these two mite species; HP 528 gave good results and was compared with aramite, parathion and two Dow materials for its residual action. They were the most effective in order: HP 528, parathion, aramite and Dow 15 and 14. HP 528 got an LD 99 and an LD 50 longer than the other materials at all concentrations. It gave an LD 99 after 40 days, at a 0.075 percent concentration. Hercules Powder 528 had less toxic effect on the plant foliage than any of them, but more phytotoxicity tests should be made before it is recommended as a mite control.

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