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ASPECTS OF THE SEASONAL FLUCTUATION OF POPULATIONS OF TETRANYCHUS URTICAE (KOCH) IN APPLE ORCHARDS IN THE STANTHORPE DISTRICT, QUEENSLAND

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SUMMARY

Populations of *Tetranychus urticae* (Koch) in a commercial orchard of Delicious apples receiving applications of broad-spectrum pesticides were determined during spring by tanglefoot traps, during summer by extraction of mites from leaf samples and during autumn by shelter traps. These showed that approximately 220 mites per tree were present during spring, 124,000 per tree during late summer and 23,000 per tree during autumn.

The mites overwintered chiefly in litter near the bases of the trees and surviving individuals migrated back to the trees during spring at approximately the green-tip stage of development of the host. Over 98% of these individuals were accounted for in traps within 3 ft of the ground and this provides the explanation for the concentration of the population in this portion of the trees in early spring. Alterations of the amount of litter at the bases of the trees during spring altered leaf populations on the trees in summer.

Calculations based on laboratory determination of population growth potential showed that the summer orchard population was 60% of the theoretical population which could develop from individuals present in spring. This showed that population growth at these levels was close to the intrinsic rate of natural increase.

Mortality of the overwintering mites in an experiment simulating natural litter conditions was approximately 99% and this would provide a spring population of 230 individuals per tree, which was quite close to the initial population.

Females in which the winterform stage was induced early in the autumn failed to overwinter. High summer populations caused leaf damage, which in turn resulted in premature induction of the winterform. This is proposed as a mechanism by which populations are reduced under conditions of high population pressure. The increased mortality of winterform individuals in effect represents a delayed mortality associated with overcrowding of summer populations.

I. INTRODUCTION

Determination of the optimum control measures to be used against *Tetranychus urticae* (Koch) as a pest of apples depends upon an understanding of the seasonal fluctuations in its populations and of the factors which influence them.

Pest populations of *T. urticae* in the Stanthorpe district generally result from the use of modern organic insecticides which are required for the control of other members of the apple pest complex (Bengston 1960). Prolonged application of the modern organic insecticides without the addition of an effective miticide results in extremely high mite populations which cause serious tree defoliation.

On the other hand, deletion of effective insecticides results in serious fruit loss due to insect pests. Neither serious tree defoliation nor serious fruit loss is acceptable in orchard practice.

The current work was undertaken to develop a broad picture of the seasonal fluctuations of *T. urticae* populations under conditions approximating those of commercial orchards in the Stanthorpe district. No similar work on the species has been noted in the literature.

II. MATERIALS AND METHODS

Experimental trees.—All experimental work was on bearing Delicious apple trees on the Granite Belt Horticultural Research Station of the Queensland Department of Primary Industries near Stanthorpe. These trees received routine applications of carbaryl 0·1% in accordance with current recommendations (Bengston 1960). All trees were planted at a 20 ft by 20 ft spacing and clean cultivation was practised during the summer months. A winter cover crop of Black Winter rye, a non-host, was grown in the period from April to August. Occasional weeds were present but in effect the only hosts for *T. urticae* in the orchard were the apple trees themselves.

Estimation of migrating populations during spring.—During spring, migrating populations were assessed by means of tanglefoot traps around the butt of trees. A band of adhesive cellulose tape ¾ in. wide was fastened in position and a resin-castor oil tanglefoot was smeared over its exposed surface. Bands were replaced daily or weekly as required for the particular experiment but in addition were replaced as soon as practicable after rainfall.

The total number of mites per tree was estimated by means of butt bands which were maintained on each of 20 trees from September 12 until September 26, 1966. The butt bands completely encircled the tree butts at a height of approximately 1 ft above ground level.

The time of migration of the mites was investigated by positioning butt bands on trees for an interval of 24 hr, with a new undisturbed tree being banded each day from September 12 to October 27, 1966.

The distribution of migrating mites on trees was investigated by similarly banding the tree butts, and in addition the tree leaders, at heights of 3, 6 and 9 ft above the ground. These heights were selected so that, for the particular tree shape involved, the trees were divided into approximately four equal portions by the bands. The bands were positioned for a 24 hr interval, with a new undisturbed tree being banded each day from September 13 to 23, 1966.

Numbers of mites moving on the orchard floor were estimated by means of tanglefoot traps placed on hardwood stakes driven into the orchard soil at intervals across the inter-tree spaces. Stakes were 1 in. square and 1 ft high, with the tanglefoot trap 6 in. above ground level. Stakes were placed in a straight line at intervals of 2 ft in the inter-tree space directly from one tree to the next. An additional stake was placed 1 ft from each tree, so there were 11 stakes in each inter-tree space. A total of 88 stakes covering 8 inter-tree spaces was used. Four of the inter-tree spaces were oriented approximately north-south and four approximately east-west. Traps were maintained from September 12 to November 4, 1966.

Litter alteration experiment.—An experiment was undertaken to determine the effect of alteration of the concentration of litter at the base of the trees on subsequent mite populations.

A 4 x 7 randomized block layout was used. Treatments were as follows:—

(1) Litter unchanged.

(2) Litter removed.

(3) Litter removed and tanglefoot applied to tree butts.

(4) Litter added from treatments 2 and 3.

Trees in the orchard were clean-cultivated except for an area approximately 4 ft square at the base of each tree. This area contained a considerable amount of leaf litter. In treatments which required the removal of litter this was carefully removed by hand. In treatment 4, which required litter to be added, the litter previously removed from trees in the other treatments was distributed over the litter present naturally. This operation was carried out on September 16, 1966, just prior to the green-tip stage in this block of trees. The term green-tip refers to the stage of development of apple trees when the new season's leaves are about half an inch in length. It represents the time at which the first new apple foliage is available to overwintering mites.

Estimation of summer foliage populations.—Summer populations were assessed by extracting mites from foliage samples. The various pieces of equipment used are shown in Figure 1. One hundred mature leaves were picked from each tree and placed immediately into a 2 lb jar containing 5% formalin; the jar was shaken vigorously to ensure rapid penetration of the formalin.

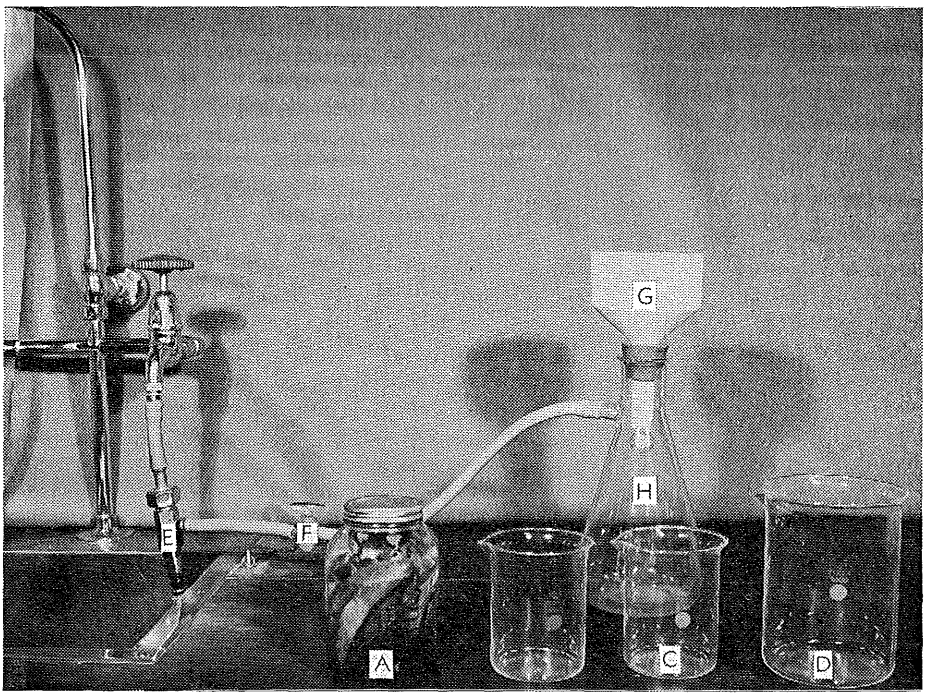

Fig. 1.—Apparatus used for extracting mites from leaf samples. A, jar containing formalin; C, beaker for draining water from jar after second shaking; D, beaker for draining water from jar after third shaking; E, filter pump; F, glass tap; G, Buchner funnel; H, vacuum filter flask. The unmarked beaker is for draining formalin from the jar.

In the laboratory, the jars were again shaken thoroughly and the liquid was then drained into a 400 ml beaker. This process was repeated using water and the liquid was drained into a second beaker. The leaves were rinsed a third time and the rinse water was poured into a 1,000 ml beaker. The leaves were placed in this water a few at a time and were stirred to dislodge any remaining mites before being discarded.

The liquid from all three beakers was then filtered off under vacuum, using a Buchner funnel and vacuum filter flask.

Black filter paper was used as this provided the best background for counting. Prior to filtering, three rectangular sample areas, each one-twentieth of the total, were marked on each paper in white indian ink, using a standard template.

All mites in the sample areas were counted under a binocular stereoscopic microscope at a magnification of 20 diam.

Estimation of autumn populations.—Corrugated cardboard bands 2 in. wide were fastened round the butt of each of 20 trees, from February 24 to June 9, 1967, to provide a shelter trap for overwintering mites which had moved downwards on the trees. The entire band was then removed; mites were extracted, using 95% ethanol, and counted according to the technique described for estimation of the foliage populations.

Experiment on time of induction of winterform.—An experiment was undertaken to determine the relationship between time of induction of winterform and the subsequent survival of the winterform individuals. Three commencement times each combined with two experimental environments were used with 12 replicates in each combination. Percentage survival in each replicate was determined on approximately 100 caged individuals.

Winterform mites were obtained by placing corrugated cardboard bands round the butts of Delicious apple trees in the field. New bands were placed in position 3 days before winterform mites were required for each time of commencement. This ensured an adequate supply of mites of reasonably uniform age. Dates of commencement were March 9, April 6 and May 4, 1967. Cages for the experiment consisted of 9 cm clear disposable plastic petri dishes ventilated with two 20 mm diam. holes covered with fine copper gauze.

For treatment A (0°C and 85–90% relative humidity), the mite cages were placed in a sealed container with its atmosphere in equilibrium with a saturated solution of potassium nitrate, and maintained at $0 \pm 0 \cdot 5$°C.

For treatment B (field conditions), the mite cages were placed on the ground near the butts of apple trees in the experimental orchards. The cages were lightly covered with the natural litter present in the area. This approximated the natural field conditions under which mites overwinter.

Mites were examined under a dissecting microscope and classified as alive or dead. In doubtful cases those capable of slight movement were classified as alive. Dead individuals were removed from the cage. All mites were removed from experimental conditions for approximately 30 min to make the necessary observations. Assessments were made at approximately monthly intervals for 6 months. Actual dates are given with the results in Table 4.

III. RESULTS

Number of winterform mites per butt band in spring.—The mean number of mites per tanglefoot trap maintained on tree butts during the period of active spring migration was $219 \cdot 9 \pm 55 \cdot 1$. The range was from 16 to 1,228.

Time of movement of winterform mites on apple tree butts.—Numbers of mites taken daily in tanglefoot traps on tree butts are plotted in Figure 2. It is

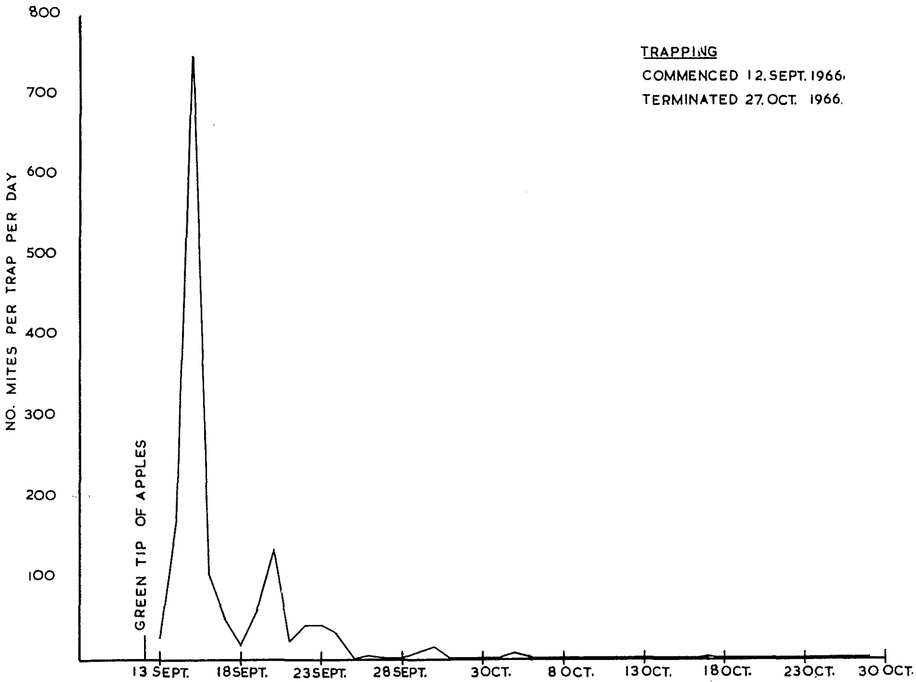

Fig. 2.—Number of *T. urticae* mites taken in tanglefoot traps positioned on apple tree butts for 24 hr intervals.

apparent that the bulk of the mites moved onto the trees during the fortnight after the green-tip stage of apples, which occurred on September 12 in this particular block.

Number of winterform mites trapped on various portions of an apple tree.—The numbers of mites taken in tanglefoot traps at the various positions on trees are shown in Table 1, together with appropriate means and standard errors. The number of mites at each position is also shown as a percentage of the total. It is interesting to note that over 98% of mites were trapped by the bands placed within 3 ft of the ground.

TABLE 1

Number of *T. urticae* Mites Taken in Tanglefoot Traps Positioned for 24 hr Intervals at Various Positions on Apple Trees, September 13–23, 1966

Position on Tree	Range	Mean ± Standard Error	Percentage of Total
Butt	18–748	143·7 ± 69·1	89·3
3 ft high	1–112	32·1 ± 11·0	9·1
6 ft high	0– 14	4·8 ± 1·8	1·4
9 ft high	0– 2	0·7 ± 0·4	0·2

Number of mites trapped on orchard floor.—Total numbers of mites trapped at approximately weekly intervals on hardwood stakes positioned across the orchard floor are given in Figure 3. These data indicate that most of the movement of winterform females occurred in the fortnight following the green-tip stage of apples (approximately September 12).

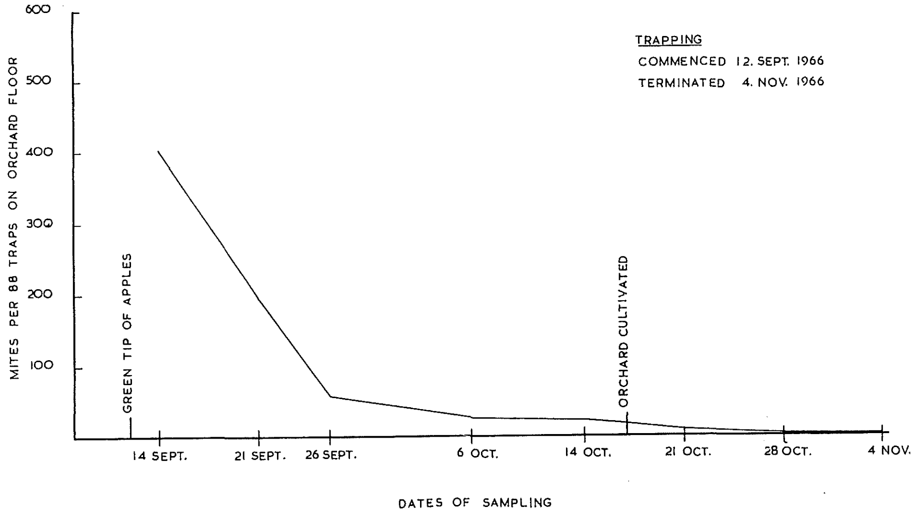

Fig. 3.—Number of *T. urticae* mites taken weekly in tanglefoot traps positioned on hardwood stakes on orchard floor.

Mean numbers of mites taken at each trapping position over the entire period are plotted in Figure 4. Trapping positions are plotted in relation to their distance from the nearest tree. Figure 4 is consistent with the observation that most mites were present in litter adjacent to the butts of trees. Numbers trapped in the inter-tree spaces indicate movement of mites between trees.

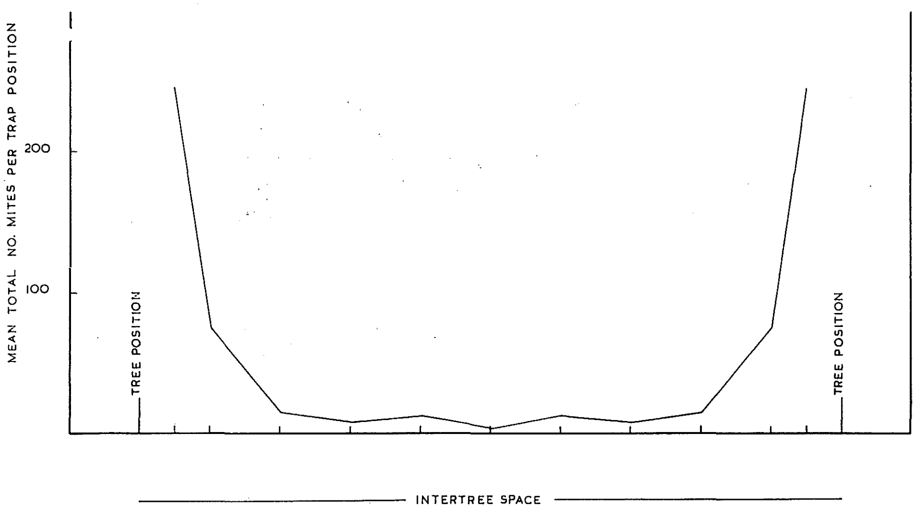

Fig. 4.—Mean total number of *T. urticae* mites taken in tanglefoot traps on hardwood stakes placed at various positions on orchard floor for the period September 12, 1966, to November 4, 1966.

Litter alteration.—Several preliminary leaf samples were taken from trees in the litter alteration experiment during the spring and early summer months, but mite numbers were too low to allow the possibility of demonstrating differences due to treatment. A single complete sampling on January 10, 1967, was warranted. At this date populations of European red mite (*Panonychus ulmi* (Koch)) were also increasing and a miticide application for the control of both species was required. Further sampling was therefore not justified.

The results of analyses of variance on both numbers of mites and numbers of eggs are presented in Table 2. They indicate a highly significant increase in number of mites present on trees in treatment 4, which had approximately three times the normal quantity of litter. Variability was high and no real differences are apparent among the remaining treatments.

TABLE 2

Effect of Alteration of Litter Concentration at the Base of Apple Trees on Subsequent Population of *T. urticae* on Apple Foliage, January 10, 1967

Treatment	Number of Mites per 15 Leaves	Number of Eggs per 15 Leaves
1. Litter unchanged	26·57	19·10
2. Litter removed	26·38	12·76
3. Litter removed and tanglefoot on butt	29·57	15·67
4. Litter added from 2 and 3 ..	82·24	25·90
L.S.D. 5%	28·94	16·70
L.S.D. 1%	39·65	22·88
	4 ≫ 1, 2, 3	N.S.D.

The numbers of mites taken weekly in tanglefoot traps on butts of trees in treatment 3 are given as a range, together with mean and standard error, in Table 3. Variability was again high, as indicated by the range and standard errors calculated. It is evident that most of the migration from ground to the trees took place in the 2 weeks after green-tip.

TABLE 3

Numbers of *T. urticae* Taken per Week in 7 Tanglefoot Traps on Butts of Delicious Trees with Litter Removed (Treatment 3) during Spring and Summer of 1966–67

Date	Range	Mean ± Standard Error
September 26	1–109	56·1 ± 17·93
October 5	1–38	10·7 ± 5·07
October 12	0–19	4·9 ± 2·77
October 19	0–13	2·6 ± 1·77
October 27	0– 0	0·0
November 3	0– 1	0·1
November 10	0– 2	0·3
November 17	0– 0	0·0
November 24	0– 2	0·3
December 1	0– 1	0·1
December 8	0– 0	0·0
December 15	0– 1	0·1
December 23	0– 0	0·0
December 30	0– 1	0·1
January 6	0– 0	0·0
January 13	0– 0	0·0

TABLE 4

EFFECT OF TIME OF INDUCTION OF WINTERFORM ON SURVIVAL OF *T. urticae* UNDER TWO OVERWINTERING CONDITIONS

Treatment	Survival Percentage									
	May 4		June 15		July 27		August 24		September 14	
	Trans.* Mean	Equiv. Mean	Trans.* Mean	Equiv. Mean	Trans.* Mean	Equiv. Mean	Trans.* Mean	Equiv. Mean	Trans.* Mean	Equiv. Mean
Treatment 1 O°C and 85–90% R.H.										
1. Commenced Mar. 9 ..	1·114	80·5	1·083	78·0	0·858	57·2	0·679	39·5	0·623	34·0
2. Commenced Apr. 6	1·397	97·0	1·296	92·6	1·258	90·5	1·216	88·0	1·200	86·9
3. Commenced May 4	..	..	1·414	97·6	1·333	94·5	1·242	89·6	1·224	88·4
L.S.D. 5%	0·063		0·070		0·098		0·100		0·103	
1%	0·085		0·094		0·132		0·135		0·138	
	$1 \ll 2$		$1 \ll 2 \ll 3$		$1 \ll 2, 3$		$1 \ll 2, 3$		$1 \ll 2, 3$	
Treatment 2 Field										
1. Commenced Mar. 9 ..	0·377	13·5	0·218	4·7	0·157	2·4	0·049	0·2	0·000	0·0
2. Commenced Apr. 6	1·159	84·0	0·450	18·9	0·263	6·8	0·080	0·6	0·009	0·0
3. Commenced May 4	..	..	0·694	40·9	0·513	24·1	0·206	4·2	0·115	1·3
L.S.D. 5%	0·150		0·156		0·133		0·080		No analyses warranted	
1%	0·203		0·210		0·179		0·107			
	$1 \ll 2$		$1 \ll 2 \ll 3$		$1, 2 \ll 3$		$1, 2 \ll 3$			

* The inverse sine transformation was used prior to analysis.

Number of winterform mites per tree in autumn.—The mean number of mites per tree taken in shelter traps during autumn was 23,154 ± 3,651, with a range of 963 to 40,073.

Time of induction of winterform.—The percentage survival of winterform individuals both in commercial orchard conditions and under controlled environment conditions was analysed after using an inverse sine transformation. A summary of the analysis is given in Table 4 and equivalent means of the percentage survival are plotted in Figure 5.

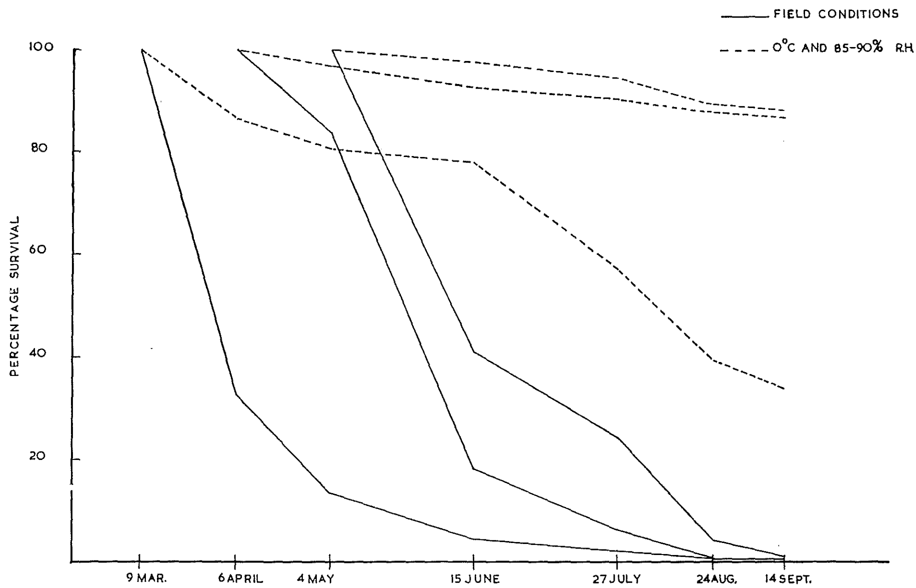

Fig. 5.—Effect of time of induction of winterform on equivalent mean percentage survival of *T. urticae* at 0°C and 85-90% relative humidity, or in field conditions in the Stanthorpe district.

At 0°C and 85–90% relative humidity, survival for winterform individuals collected in March was less than for those collected in April or May. Survival for those collected in April was slightly less than for those collected in May, but this difference was statistically significant only on June 15.

Under conditions approximating those occurring in the commercial orchard, survival of individuals collected during March was significantly less than of those collected in April or May during the first 2 months after collection. This difference was obscured later in the winter as normal survival dropped to low levels. Survival of individuals collected during April was significantly less than of those collected during May.

Analyses of variance were undertaken on percentage survival of winterform individuals over approximately equal periods of time (20–21 weeks) and the results are given in Table 5. Under controlled environment conditions, survival of individuals collected in March was less than that for individuals collected in either April or May. Survival in the field over this period of time was low, so no significant differences are apparent.

TABLE 5

EFFECT OF TIME OF INDUCTION OF WINTERFORM ON SURVIVAL OF *T. urticae* OVER EQUAL LENGTHS OF TIME

Duration of Treatment	Survival Percentage			
	0°C and 85–90% R.H.		Field	
	Trans.* Mean	Equiv. Mean	Trans.* Mean	Equiv. Mean
1. March 9–July 27 ..	0·858	57·2	0·157	2·4
2. April 6–August 24	1·216	88·0	0·080	0·6
3. May 4–September 14	1·224	88·4	0·115	1·3
L.S.D. 5%	0·103		0·095	
L.S.D. 1%	0·139		0·127	
	1 ⩽ 2, 3		N.S.D.	

* The inverse sine transformation was used prior to analysis.

Analyses of variance were also carried out to compare survival at 32°C and 85–90% relative humidity with survival under the simulated commercial orchard conditions. Results are given in Table 6. Survival was markedly greater under controlled environment conditions and the difference is statistically significant for all occasions which warranted analysis. No individuals survived from March to the green-tip stage of apples in September under the field conditions. One individual only from a total of 1,215 individuals survived from April to September, while 29 from a total of 1,454 individuals (2%) survived from May to September. Of the grand total of 3,296 individuals at the commencement of the experiment, 30 (just under 1%) survived until the green-tip stage of apples in September.

IV. DISCUSSION

(a) Winterform Mites in Spring

The various data collected were used in the attempt to measure both the number and the location of successful overwintering mites. The data were consistent with the observation that *T. urticae* overwinters chiefly in litter close to the base of the apple trees. In the block of trees studied, 220 mites per tree were taken in tanglefoot traps on the tree butts. This figure is probably an underestimate of the number of mites which would otherwise have infested the trees. Some mites were present in litter in the forks of the trees and in addition others were already moving on the trees themselves. Further numbers of individuals probably were present on developing buds. On the other hand, it is by no means certain that all these individuals would have actually reached the new apple foliage. It was difficult to decide the most appropriate time to commence trapping. If it were commenced too

TABLE 6

EFFECT OF OVERWINTERING CONDITIONS ON SURVIVAL OF WINTERFORM *T. urticae* FOR VARIOUS TIMES OF INDUCTION OF WINTERFORM

Treatment	Survival Percentage											
	April 6		May 4		June 15		July 27		August 24		Sept. 14	
	Trans.* Mean	Equiv. Mean	Trans. Mean	Equiv. Mean	Trans. Mean	Equiv. Mean	Trans. Mean	Equiv. Mean	Trans. Mean	Equiv. Mean	Trans. Mean	Equiv. Mean
Commenced March 9												
1. O°C and 85–90% R.H. ..	1·194	86·4	1·114	80·5	1·083	78·0	0·858	57·2	0·679	39·4	0·623	34·0
2. Field	0·610	32·8	0·377	13·5	0·218	4·7	0·157	2·4	0·049	0·2	0·000	0·0
L.S.D. 5%	0·141		0·097		0·115		0·120		No analyses warranted		No analyses warranted	
1%	0·191		0·131		0·156		0·162					
	1 $\geqslant$ 2		1 $\geqslant$ 2		1 $\geqslant$ 2		1 $\geqslant$ 2					
Commenced April 6												
1. O°C and 85–90% R.H. ..			1·397	97·0	1·296	92·6	1·258	90·5	1·216	88·0	1·200	86·9
2. Field			1·159	84·0	0·450	18·6	0·263	6·8	0·080	0·6	0·009	0·0
L.S.D. 5%			0·130		0·126		0·095		0·089		No analyses warranted	
1%			0·177		0·172		0·130		0·121			
			1 $\geqslant$ 2		1 $\geqslant$ 2		1 $\geqslant$ 2		1 $\geqslant$ 2			
Commenced May 4												
1. O°C and 85–90% R.H. ..					1·414	97·6	1·333	94·5	1·242	89·6	1·224	88·4
2. Field					0·694	40·9	0·513	24·1	0·206	4·2	0·115	1·3
L.S.D. 5%					0·129		0·138		0·088		0·091	
1%					0·176		0·188		0·120		0·124	
					1 $\geqslant$ 2		1 $\geqslant$ 2		1 $\geqslant$ 2		1 $\geqslant$ 2	

* The inverse sine transformation was used prior to analysis.

early, individuals would be trapped which were not true survivors. If it were commenced too late, individuals would have commenced leaf feeding and would not be taken in tanglefoot traps.

Data on the number of winterform mites taken on various portions of the trees indicate that mites were already present over most of each tree by the green-tip stage. The trapping itself would interfere with any directed migration, although restriction of the trapping to a 24 hr interval should have reduced this interference. Data suggest that most mites during winter were present near the butt of the trees. The new season's leaves close to the base of a tree, therefore, would have a greater chance of becoming infested. This is the basis of the common field observation that *T. urticae* populations commonly develop from the base of the trees.

The determination that over 98% of overwintering mites were trapped within 3 ft of the ground would suggest that miticide applications at the time of mite migration back to the trees could be restricted to the lower zone of the trees during the early spring.

Data on the number of mites taken on the orchard floor indicate that most mites were present near the bases of the trees. In addition, leaf litter in the inter-tree spaces is largely destroyed by cultivation, but litter close to the base of the trees is undisturbed. The number of mites taken in traps throughout the inter-tree space indicates that some mites move across the orchard floor during spring. This would assist in dispersal of the species and would tend to equalize populations among trees, but it also presumably results in additional loss of the overwintering population.

(b) Effect of Litter Alteration on Developing Population

Results indicate that alteration of litter at the base of the trees resulted in altered leaf populations developing almost 4 months later. While trees with added litter had greater populations than unchanged trees, the trees from which litter was removed did not have significantly smaller populations. The most likely explanation of this anomalous result lies in the variability of the populations on each tree. Removal of about 70 mites per tree, or about one-third of the population, by sticky banding in treatment 3 did not produce a significantly lower leaf population than treatment 2, which was identical in other respects.

The lengthy period between removal of litter and the development of a measurable population probably helped to mask differences. Counts were made before appreciable tree damage became obvious and populations were therefore related to treatments influencing the number of overwintering mites. Trees with the highest population (treatment 3, litter added) had about three times the population of the other trees, including those from which the litter was removed. With a population rate of increase of 0·11 per day a population will treble itself in a week. Such a rate of increase has been measured under field conditions in the area and will be discussed later. Litter alteration alone therefore seems unlikely to provide sufficient control of *T. urticae* in apple orchards in the Stanthorpe district.

(c) Winterform Mites in Autumn

Shelter traps on the butt of trees were effective as a means of population measurement during autumn because *T. urticae* winterform females are positively geotactic (Foott 1965) and negatively phototropic (Hussey and Parr 1963). The technique, however, underestimated the size of the overwintering population because some individuals remained on the trees above the shelter traps and some migrated past the traps to the litter. Nevertheless, the data provide a useful broad estimate of the population level.

In the study orchard a mean of 23,000 winterform mites per tree were present in the autumn. This compared with a figure of 220 survivors in the spring, suggesting a mortality or loss of about 99% of the population. Both estimates were underestimates, so they should partially balance for the estimate of mortality. With a sex ratio of unity the total autumn adult population of the leaves would be 46,000, since mated males perish on the trees without migrating and are not included in the counts.

(d) Seasonal Population Fluctuations in the Study Orchard

The data from the various sections of the study can be used to present a composite account of the mite populations throughout the year in the study orchard (Figure 6). Certain assumptions and approximations will be inevitable. It will be most convenient to consider the population in terms of mites per tree and it will be necessary to establish a factor for conversion of data recorded in terms of mites per leaf to mites per tree.

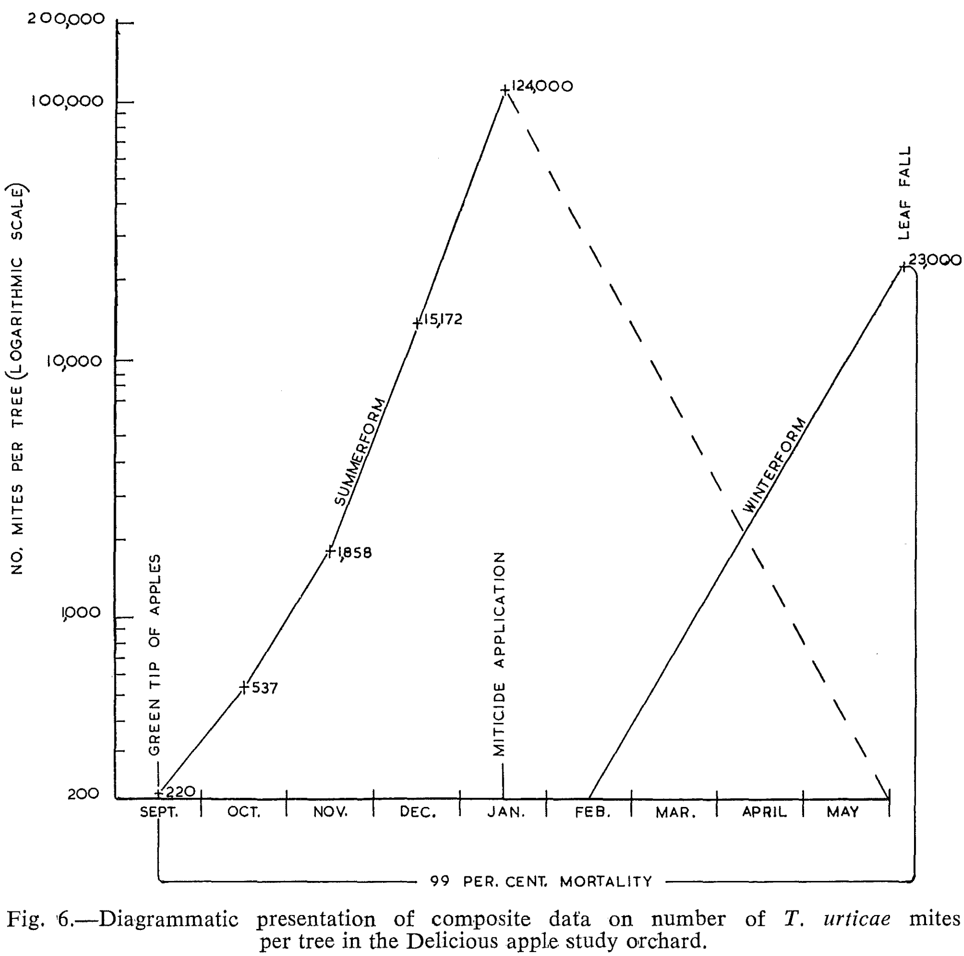

Fig. 6.—Diagrammatic presentation of composite data on number of *T. urticae* mites per tree in the Delicious apple study orchard.

Batjer, Rogers and Thompson (1952) estimated that 30-year-old Delicious apple trees in Washington State averaged 150,000 leaves per tree. Unpublished Queensland data available on fruit yields, tree size, age and spacing suggest that trees used in the current work were approximately one-fifth of the size of those measured by Batjer and associates. A figure of 30,000 leaves per tree therefore seems appropriate.

Direct estimation of the population per tree during the months from October to December was not possible. With approximately 220 mites initially present per tree in the spring and to be distributed later on 30,000 leaves, it is obvious that fewer than 1 mite would be expected per 100 leaves of the standard field sample.

In the absence of direct data the theoretical number of mites per tree for the early to midsummer months was calculated from the initial number. Relevant data from earlier work by the author (Bengston 1969) on the rate of population increase under constant temperature and relative humidity conditions were used. Standard meteorological data were used to estimate the appropriate temperatures and relative humidities. Population levels were calculated at monthly intervals.

Prevailing temperatures and relative humidities, appropriate rates of population increase and theoretical numbers of mites per tree for relevant months are given in Table 7.

TABLE 7

CALCULATED POPULATION LEVELS OF *T. urticae*, TEMPERATURE AND RELATIVE HUMIDITIES, AND RATES OF POPULATION INCREASE, 1966–67

Date	Temperature (°C)	Relative Humidity (%)	Rate of Increase per Day		Mites per Tree
			Clover	Delicious Apple	
Mid September ..	12·0	66			220 winterform
Mid October 12 ..	15·5	63	0·05	0·04	537 eggs
Mid November 12	18·5	63	0·09	0·07	1,858
Mid December 12	20·5	64	0·11	0·09	15,172
Mid January 10 ..					206,339

The net reproduction rate for post-winter form females at 11·5°C with a mean of high and low relative humidity levels is 1·22 (Bengston 1969). Allowing for production of an equal number of males, 2·44 eggs per winterform female are anticipated with a mean time of oviposition of October 12.

It is worth emphasizing that the population is heavily dependent on the temperature and relative humidity conditions prevailing during the second half of September. A rise of 5°C increased the egg-laying capacity of winterform females by a factor of 9 (Bengston 1969).

From October 12 it was possible to use the appropriate intrinsic rate of increase as the theoretical rate of population growth. Appropriate values for clover as host were estimated and a correction factor of 0·822 applied to approximate those for Delicious apples. The theoretical population on January 10, 1967, was 206,339 mites per tree. Actual sampling showed that the mean number of individuals per leaf on all trees in the study orchard on January 10, 1967, was 4·14, and this is the equivalent of 124,420 individuals per tree. This is 60% of the theoretical population and a tolerably good agreement under the circumstances. The actual rate of population increase would tend to be below the intrinsic rate of natural increase.

No miticides were applied to the study trees prior to January 10, 1967; however, an application immediately after this date interfered with any further detailed studies.

The autumn winterform population migrated from foliage to the base of the tree from February to May and an estimated 23,000 winterform individuals per tree entered this stage.

Only 1% of winterform individuals survived to green-tip and this suggests 230 survivors per tree in the spring. An average of 220 was actually sampled.

The close agreement of these data is fortuitous in view of the high variability and likely sources of error inherent in work of this nature. For example, the use of a cage to confine the winterform mites induces unnatural conditions. Nevertheless, the agreement suggests that the overall picture is a realistic one.

(e) Population Fluctuations in Other Seasons

Data were available from various miticide screening trials carried out by the author on Delicious apples in the Stanthorpe district independent of the current project. These data are incomplete and relate to a wide variety of conditions but they serve to indicate a broad pattern of population fluctuations.

The relevant data are shown in Figure 7. Rate of increase varied from 0·02 to 0·11. With the exception of the latter value, these are all lower than the comparable intrinsic rate of natural increase for prevailing temperatures and relative humidities (Bengston 1969). This was to be anticipated because most of the populations sampled were so high that overcrowding and leaf damage had occurred. It is probably significant that the highest rate of increase recorded involved a low population early in the season.

It is interesting to note that a rate of increase of 0·04 was recorded at population levels of 100 mites per leaf or 3 million per tree. It was also interesting to calculate that had a miticide not been applied it would have required only a rate of increase of 0·10 for this population level (recorded on February 7, 1966) to develop in the equivalent 28 days from the one present in the study orchard on January 10, 1967.

(f) Time of Induction of Winterform

Data on survival of winterform individuals suggest a mechanism whereby populations are balanced to the apple host at least under outbreak conditions. High populations cause greater leaf damage, which in turn tends to induce the winterform stage prematurely in the autumn. This early induction of winterform reduces the individual's chance of surviving to the next spring. High populations are thus reduced while low ones can continue to increase. This mechanism could in part provide the explanation for the field observation that a very severely damaged apple orchard one season may have few mites in the next.

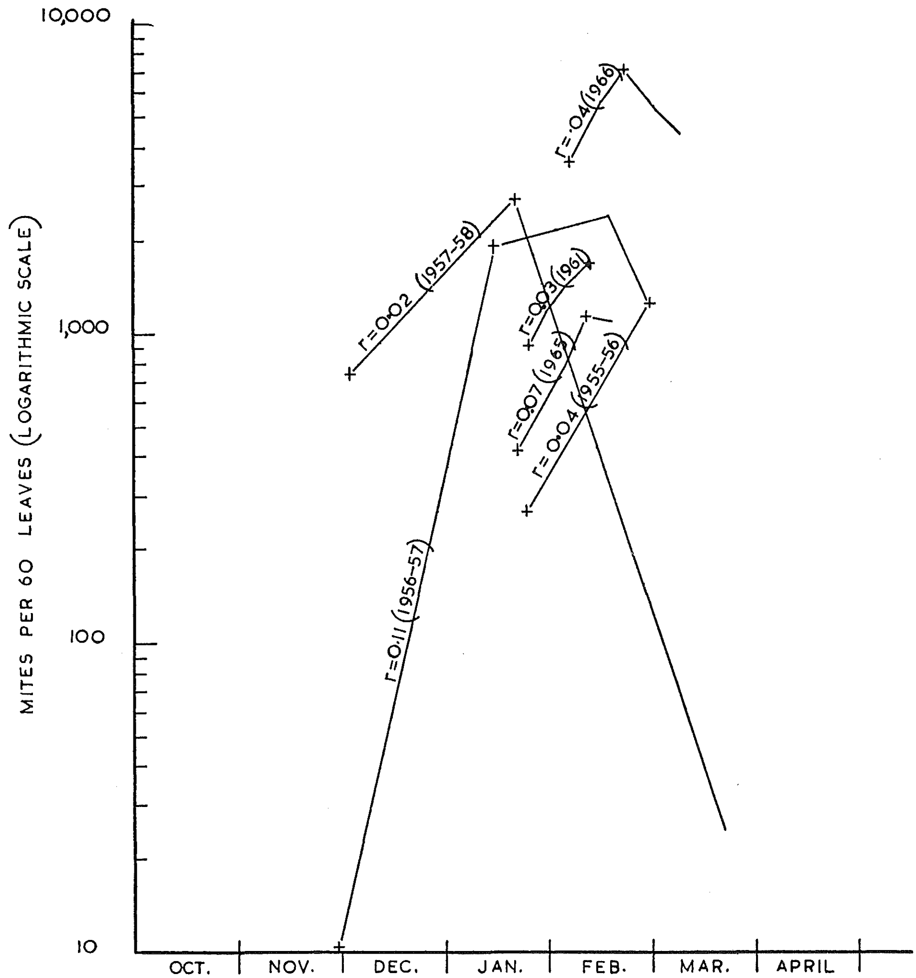

Fig. 7.—Some population fluctuations of *T. urticae* mites recorded on Delicious apple trees receiving modern organic pesticides but no miticides in commercial orchards in the Stanthorpe district.

The increased mortality of winterform individuals in effect represents a delayed mortality associated with overcrowding of summer population.

Under controlled environment conditions and over comparable intervals of time, survival of winterform individuals collected in March was less than of those collected in April or May (Table 5). This suggests that some factor detrimental to survival had operated by the time the winterform individuals moved down and reached the shelter trap. This, however, could be partly explained by the higher temperatures prevailing during March. The average daily mean temperature at Stanthorpe for March is 19·1°C, for April 15·5°C and for May 11·6°C (Anon. 1956). Bengston (1965) and Parr and Hussey (1966) presented evidence that survival of winterform individuals is reduced at higher temperatures.

The suggested mechanism is also supported by the observation that orchards in better cultural conditions have a greater mite problem than those in poor condition. A complex of factors no doubt is involved but at least a partial explanation lies in the observation that such orchards carry healthy foliage later into the autumn. Induction of winterform thus occurs at a later and cooler time in the year and this in turn favours the survival of winterform individuals. Spring populations consequently may be higher and accordingly could require an increased control programme.

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