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EUROPEAN RED MITE (PANONYCHUS ULMI (KOCH)) AND ITS ADAPTATION TO THE STANTHORPE DISTRICT, QUEENSLAND

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SUMMARY

European red mite was first recorded from Queensland in 1957 and has since become a serious pest of deciduous fruit orchards in the Stanthorpe district.

Field observations over three seasons have shown that the hatching of overwintering eggs is broadly synchronized with green-tip of apples (mid September). The first deuteronymphs appear in early October and the resulting females produce summer eggs. Overwintering eggs may be laid as early as January on mite-damaged trees, but on healthy trees they are not produced until mid March.

The critical photoperiod of Stanthorpe material (latitude 28°S.) has been determined as 13 hr at 15°C, and this is evidence that strains differing in photoperiodic adaptation exist in this species.

Temperatures in the range —1° to 13°C have proved effective in terminating diapause over periods of 126 and 154 days.

The seasonal history is discussed in the light of these data. The species appears well adapted to environmental conditions prevailing in the Stanthorpe district.

I. INTRODUCTION

The first record of *Panonychus ulmi* (Koch) in Queensland was made in 1957 by the author during a pest survey of deciduous fruit orchards and it was soon revealed that the species was present in all parts of the Stanthorpe district. The mite is known to be readily dispersed as winter eggs on stock or scion wood and such wood was earlier freely imported into the district from infested areas in other States of Australia. It is therefore probable that the introduction of the mite into Queensland took place at a time much earlier than 1957 and that its presence was then not apparent.

Since 1957, district surveys have shown that the mite has persisted as a serious pest in some orchards and that it ranks second in importance to *Tetranychus telarius* (L.) in the mite complex. Although the full range of deciduous fruits is attacked, the mite is of most importance on plums and apples.

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Stanthorpe is approximately at latitude 28 degrees S. Blair and Groves (1952), working in the northern hemisphere, stated that the range of *Panonychus ulmi* was from 30 to 60 degrees latitude. Its persistence as an orchard pest in the Stanthorpe area is of interest in that this location appears to represent an extreme of its distribution.

Lees (1953) carried out extensive studies on the influence of environmental factors on the seasonal history in England. During the summer, eggs of a non-diapause type are laid on leaves and hatch without interruption. In the autumn, eggs of a diapause type are laid mainly on the bark. These so-called winter eggs constitute the overwintering stage of the species and require winter chilling before embryonic morphological development proceeds to hatching. The seasonal history of the mite is thus broadly synchronized with that of its deciduous hosts.

Lees demonstrated that photoperiod, temperature and nutrition prevailing during the sensitive deuteronymphal stage were the important factors influencing the production of summer-type or winter-type eggs. Summer eggs are laid under conditions of high temperature, long days and adequate nutrition, while contrasting conditions to these generally initiate the laying of winter eggs. Lees put forward an interpretation of the life cycle and phenology of the species in southern England (latitude 52 degrees) in the light of these data. A literal interpretation of this work would indicate that conditions of photoperiod and temperature prevailing in the lower latitude of the Stanthorpe district should induce "errors" in the seasonal history.

The work currently described was undertaken to determine whether the species has adapted itself to local conditions, and to investigate the mechanism of any such adaptation.

II. SEASONAL HISTORY

The investigations included a study of the seasonal history. This work was carried out mainly on apples, which constitute the major horticultural crop in the area. It was concentrated essentially on the points which are likely to be limiting factors to survival of the mite in the light of Lees' data.

Hatching of Overwintering Eggs.—Field observations over three seasons (1960-1962) showed that hatching of winter eggs commenced about the time of the green-tip stage of apples and continued until the calyx stage.

In the spring of 1962, twigs of Delicious apples bearing overwintering eggs were cut and placed with their lower ends in moist sand in an outside garden bed so that they were exposed to natural weather conditions. The number of mites hatching in a marked area was recorded daily. A thermohygrograph record was maintained in an adjacent Stevenson screen. Hatching commenced on

September 10 and continued for 29 days until October 9; 35 per cent. of the eggs proved viable. Data showing number of mites hatching per day, stages of development of Delicious apples, and mean daily temperature (based on 12 two-hourly readings per day) are shown in Figure 1. These data confirm the field observation that the hatching of overwintering eggs occurs at the same time as the development of leaf tissue on the host.

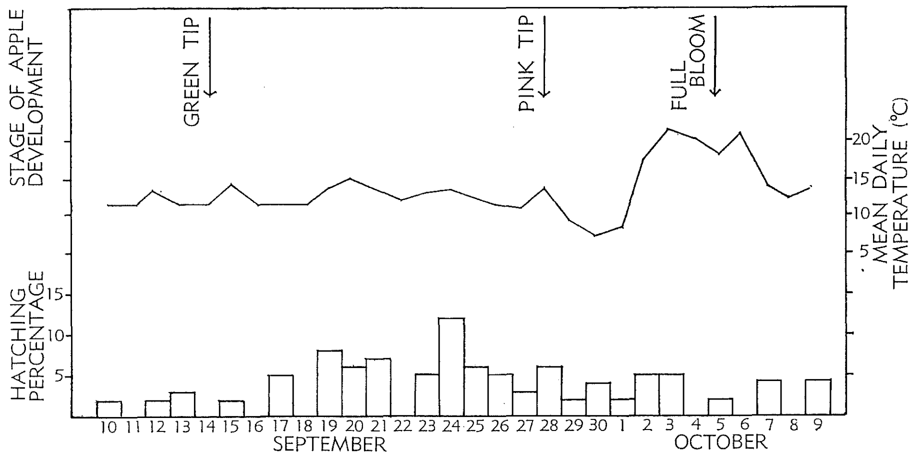

Fig. 1.—Hatching of overwintering eggs of *Panonychus ulmi*, 1962.

Miller (1952) in his work on Tasmanian material demonstrated wide fluctuations in both the duration of the hatching period (33–64 days) and the percentage of viable eggs (31–93) on a single host variety. He obtained evidence that hatching periods (minimum 11 days) and the percentage of viable eggs (minimum 21) were less on early-maturing than late-maturing varieties.

In view of this variation it is sufficiently true to state that commencement of hatching in the Stanthorpe district approximates green-tip of apples in mid September.

Egg-laying in Spring.—Field observations were made on the date of first appearance of the sensitive deuteronymphal stage. This occurred in all three seasons during the first or second week in October. Summer eggs then were observed as early as the second week in October. Despite a careful search of material colonizing current season's growth, winter-type eggs were not observed at this time of the year. This point was further investigated by introducing mites to uninfested young apple trees and making daily observations on their development. Again summer-type eggs only were observed during the month of October. It is concluded therefore that no significant percentage of winter-type eggs, if any, is laid by mites developing during the spring months.

Laying of Overwintering Eggs.—The date at which conditions of photoperiod and temperatures initiate the laying of winter-type eggs is of considerable ecological importance. Observations on the first occurrence of this phenomenon, however, have been confused by the influence of premature senescence of the leaves, which itself induces diapause. This premature senescence may be caused by mite damage or by a variety of environmental and cultural factors. On mite-damaged orchards, winter-type eggs were observed in mid January. It is probable that a more extensive search might have advanced this date. Detailed observations made daily on a block of young trees with no noticeable damage during the 1962 season showed that winter-type eggs were not laid until mid March.

Non-viable Eggs.—Under field conditions heavy populations of winter-type eggs have sometimes proved non-viable during the following season. In these instances trees which were literally red with eggs during the winter have been almost free of mites in the spring. This is in accord with the observations of Cottier (1934) in New Zealand, who suggested that the winter eggs are susceptible to a period of hot weather prior to winter temperatures.

III. INDUCTION OF DIAPAUSE

An experiment was carried out to determine the critical photoperiod of Stanthorpe mite material under controlled conditions.

The technique used was essentially the method which Lees (1953) used in the portion of his work dealing with the effects of nutrition on diapause. The necessary leaf tissue was obtained by cutting twigs of current season's growth of Delicious apples to approximately 3-in. lengths and removing all leaves except the top one. Each twig was held upright by a small pin through a piece of linoleum and pushed into the base of the twig. The linoleum bearing the twig was then placed in water in half of a petri dish with the twig base in the water. New leaves were provided in this way at weekly intervals.

Illumination was provided by twin 20-W and 40-W fluorescent tubes. All experiments were carried out in a constant-temperature room which was maintained at $15 \pm 1 \cdot 5$°C. The various photoperiods were obtained by opening and closing the lids of light-tight boxes in which the appropriate material was held.

Protonymphs for the experiments were obtained from a field collection of material on Delicious apples. These were allowed to develop under the various photoperiods and were placed singly on leaves as adults and then classified as summer or winter females strictly in accord with the criteria of Lees (1953). Winter eggs are bright orange and are laid on the bark. In doubtful cases eggs were incubated for 10 days at 25°C, when those in diapause neither shrivelled nor hatched.

Results, together with the comparable data of Lees, are given in Table 1 and Figure 2.

TABLE 1

Induction of Diapause by Photoperiod in *Panonychus ulmi*

Percentage winter females at 15°C

Material	Photoperiod (hr/24 hr)								
	0	4	8	12	13	14	15	16	24
Stanthorpe material, average 26 mites per photoperiod ..	71	92	96	81	48	21	8	5	5
English material, 15–20 mites per photoperiod (after Lees)	60	85	94	97	94	54	4	0	0

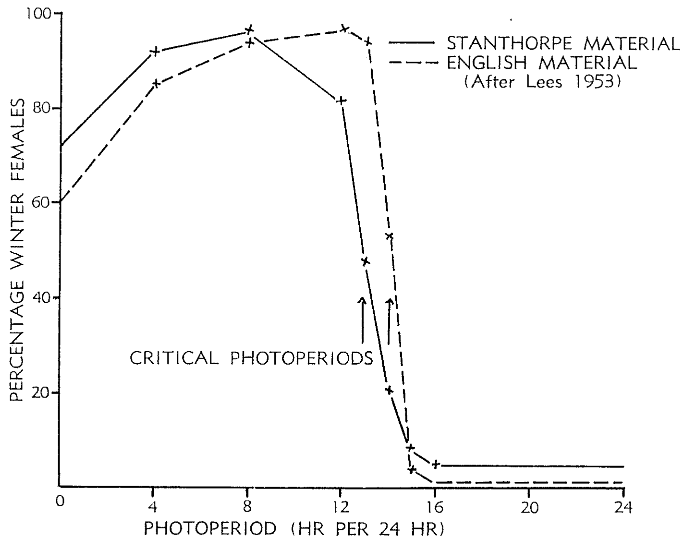

Fig. 2.—Induction of diapause in *Panonychus ulmi.*

It is evident that the same general pattern of behaviour exists in each of the two kinds of material. However, the critical photoperiod of the Stanthorpe material approximates 13 hr, in comparison with 14 hr for the English material. The occasional mites producing winter eggs under summer conditions may be due to marginal nutrition at some stage during the experiment. The shorter critical photoperiod represents an adaptation to environmental conditions prevailing at Stanthorpe.

IV. TERMINATION OF DIAPAUSE

Diapause in the winter egg is terminated by exposure to low temperatures. An experiment was undertaken to obtain data on the chilling requirements of the Stanthorpe material.

Twigs of Wilson plum bearing overwintering eggs were collected in the field on March 29, and were cut into approximately 4-in. lengths and placed singly in corked 6-in. test-tubes. This material was then stored in the dark under the selected temperature conditions. Four replicates totalling to an average of 855 mites were used at each temperature. The choice of experimental temperatures was somewhat restricted, as the controlled-temperature rooms were in use for other purposes. For this reason, temperature C (see Table 2) was 4°C from April 16 to June 25 (70 days) and was then raised to 7°C for the remainder of the experiment. Temperatures quoted were maintained with an accuracy of ± 1°C. Control material was kept in a Stevenson screen fully exposed to natural weather conditions at Stanthorpe.

Samples were withdrawn at appropriate intervals and incubated under light at 30°C until hatching was completed. Counts were then made of the total number of eggs and of the number of mites which had emerged from them. It was found during the course of the experiment that material in unsealed tubes dried out, resulting in heavy mortality. Data relating to intervals less than 126 days have therefore been excluded. Results are given in Table 2.

TABLE 2

PERCENTAGES OF EGGS HATCHING AT 30°C

Temperature	Period Exposed (Commencing April 11)			
	126 days (August 20)		154 days (September 17)	
	Transformed Mean*	Equivalent Mean	Transformed Mean*	Equivalent Mean
A Stanthorpe	0·29	8·0	0·13	1·7
B 13°C	0·35	11·7	0·10	1·0
C 4 and 7°C	0·29	7·9	0·40	15·3
D 2°C	0·17	2·8	0·30	8·5
E 1°C	0·23	5·1	0·21	4·2
F 0°C	0·16	2·5	0·37	12·8
G −1°C	0·13	1·7	0·34	11·4
H −12°C	**	0	**	0
s.e.	0·09		0·14	
Necessary differences for significance 5%	0·27		0·41	
Necessary differences for significance 1%	0·37		0·57	

* Inverse sine transformation.

** Mean excluded from analysis.

A high degree of variability is evident in the results and this would have the effect of obscuring small differences between treatments. The temperature −12°C was lethal over the period involved. A significant feature, however, is the fact that a temperature of 13°C was effective in terminating diapause. The upper limit of temperature effective in terminating diapause could probably be somewhat higher. Lees (1953) showed that the upper limit of this temperature for English material lay above 9°C. The fact that temperatures as high as 13°C were effective in the present work is important in a consideration of the winter chilling requirements of the species in the Stanthorpe district. The hatching of control material in August is also significant in this regard.

V. SEASONAL HISTORY IN RELATION TO ENVIRONMENTAL CONDITIONS

The seasonal history of *Panonychus ulmi* in the Stanthorpe district may be considered in relation to the various experimental results. Comparison with the data of Lees (1953) for southern England is made later at the appropriate points.

Actual records of photoperiodically active daylight for Stanthorpe (above 1–2 foot-candles (Lees 1953)) were not available. A number of direct measurements, however, were made of the pre-sunrise and post-sunset intervals, using a photoelectric meter. Although these are influenced slightly by cloud cover, one hour represents a reasonable approximation for the sum of both. Times of sunrise and sunset for Warwick have been published (Newell 1952, 1953) and these apply with sufficient accuracy to the Stanthorpe district 30 miles to the south. Natural photoperiods discussed in this work are therefore the sunrise to sunset interval to which one hour has been added.

de Wilde (1962) pointed out in his review article that light intensity at civil twilight approximates the critical intensity required for work on photoperiods. Data on civil twilight tabulated in the 1962 Nautical Almanac (Greenwich) were therefore used as the basis of an alternative estimate of photoperiodically active day length. A latitude of 28°30′ south and an altitude of 2500 ft were used and the results for all months agreed within 10 min of the previous estimate. This is adequate for current purposes and verified the accuracy of the data used in this discussion.

Lees (1953) demonstrated that the temperature during the hours of darkness is the important temperature relating to the induction of diapause. Actual calculation on a sample of thermohygrograph records showed that the dark temperature (mean of 5 two-hourly intervals) is given with sufficient accuracy by the formula, daily minimum plus one-quarter of the daily temperature range. This formula was applied to data published by the Bureau of Meteorology, Australia (Anon. 1957). The results (converted to centigrade), together with the data on which they are based, are given in Table 3.

TABLE 3

Maximum, Minimum and Dark Temperature

Monthly means, °C

—	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Average daily maximum temperature	20	23	26	27	28	27	25	22	18
Average daily minimum temperature	5	9	12	14	15	15	13	9	5
Dark temperature	8	12	16	17	18	18	16	12	8

Since late October and mid March are the important times in a discussion of the influence of photoperiod, a dark temperature of 15°C was used in this work.

Natural photoperiods and salient times in the seasonal history of the species for both Stanthorpe conditions and those of southern England (after Lees 1953) are shown in Figure 3.

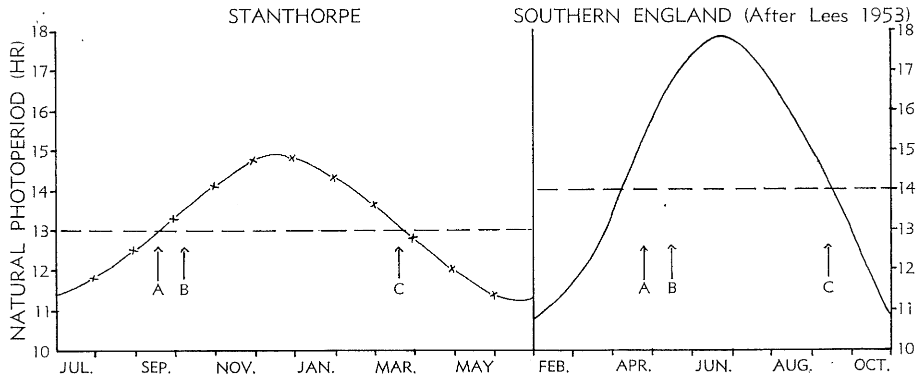

Fig. 3.—Natural photoperiods and seasonal history of *Panonychus ulmi*.

In the field, overwintering eggs commence to hatch during September. By this time they have been exposed to fluctuating cool temperatures for some 6 months. Data calculated from thermohygrograph charts (unpublished Departmental records) indicate that approximately 120 days of this period are at temperatures at or below 13°C, which has been shown to be effective in terminating diapause. (The corresponding interval below a temperature of 9°C is something less than 70 days.) It is thus unlikely that insufficient winter chilling is a limiting factor in the adaptation of the species to, and existence under, Stanthorpe conditions. The demonstration that diapause was already terminated under natural weather conditions at Stanthorpe by July and August (over a month prior to field hatching) supports this contention. Hatching in September occurs in response to rising temperatures.

The first members of the overwintering generation reach the sensitive deuteronymphal stage in early October. By this time the natural photoperiod approximates 13½ hr. The critical photoperiod was shown to be 13 hr, so the majority of the mites are expected to produce summer eggs.

Photoperiods (and temperatures) then increase during the summer months and do not again decrease to the critical level till the last week in March. This agrees well with the observation that overwintering eggs are not produced until mid March on trees where nutrition is presumably adequate. The presence of winter eggs from January onwards on trees suffering from mite damage, drought and other adverse effects is due to the overriding influence of poor nutrition (Lees 1953; Miller 1952).

By mid March many of the orchards in the Stanthorpe district are already undergoing some senescence. This is of course a variable feature, but there is a tendency for the nutritional factors to be more important than the photoperiod influence.

de Wilde (1962) has shown that there are several mechanisms by which the photoperiodic response of local strains of a species may vary with geographical latitude. It may be concluded from the current work that strains of *Panonychus ulmi* exist and that these vary in their critical photoperiods while the photoperiodic response remains intense. The data show that the species is sufficiently well adapted to environmental conditions prevailing in the Stanthorpe district to enable it to persist as an important orchard pest.

VI. ACKNOWLEDGEMENTS

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