THE EFFECTS OF PHOTO-STIMULUS ON THE THERMAL REACTION IN FOUR SPECIES OF SPIDER MITES

(ACARINA: TETRANYCHIDAE)

By

Hans MORI

Institute of Applied Zoology, Faculty of Agriculture,
Hokkaido University, Sapporo

INTRODUCTION

In a previous paper the author has reported about the distinct temperature preference of each of four species of spider mites. The temperature preference of each species is as follows: *Panonychus ulmi* 25°–28°C., *Bryobia praetiosa* 21°–24°C., *Tetranychus viennensis* 25°–30°C. *T. telarius* usually prefers the lower temperatures within the range of 13°–35°C. (MORI 1961). Moreover, it has been proven by the author's experiments that each mite shows positive phototaxis to white light (MORI 1962). It is noted that the stimuli of temperature and light strongly control the behaviour of the mites. The present paper deals with experiments on the behaviour of each of four species of spider mites under the combinations of thermo-stimulus and photo-stimulus.

MATERIALS AND METHODS

As the apparatus for the experiment an alternative chamber was employed. A half of the upper surface of the chamber was covered with black paper so that the half of the arena would be kept in darkness, while the other half was in the light. An electric lamp (60 watts, 100 volts) was used at 45 cm above the apparatus. The temperature in each half of the alternative chamber was regulated into several grades from 44°C. to 13°C.

Experimental materials were the same four species of spider mites as those employed in the previous experiment (MORI 1961). The mites were collected from apple trees in Sapporo from July to September, 1959. They were kept on potted apple trees in the laboratory for more than one day, and then transferred to a dark room together with the potted apple tree for three hours before experiment.

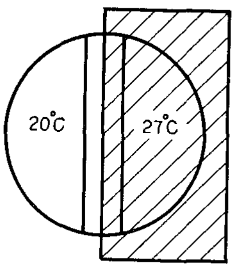
[Journ. Facul. Agr., Hokkaido Univ., Sapporo, Vol. 52, Pt. 1, 1962]

At the start of the experiments, 9 to 22 mites were put on the intermediate zone along the 4 cm wide mid-line in the chamber. The number of mites on each side of the chamber was counted for 35 minutes at intervale of 5 minutes.

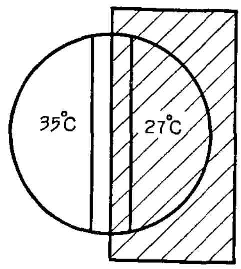
During the progress of the experiment, several combinations of illumination and temperature set up in the alternative chamber were designed according to the following schemata (A, B, C, D, E and F).

Explanation of schemata (The case of *P. ulmi* taken for an example).

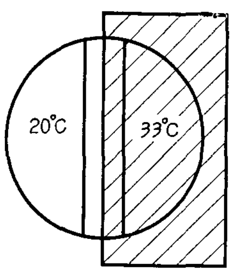
The experiments of B′ and B″ were made in order to prove the terminal point of temperature at which the tendency of photo-kinesis of mites was reduced.



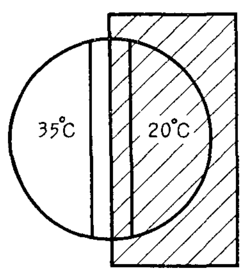
A : The dark side was held at the preference temperature of *P. ulmi*. The light side was held at a temperature lower than the optimum of this species.



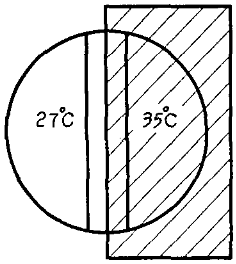
B : The dark side was held at the preference temperature of *P. ulmi* like A. The light side was held at a temperature higher than the optimum of this species.



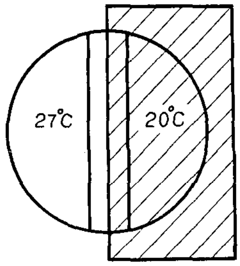
C: The dark side was held at a temperature higher than the optimum for *P. ulmi*, and the light side was held at a temperature lower than the optimum of this species.



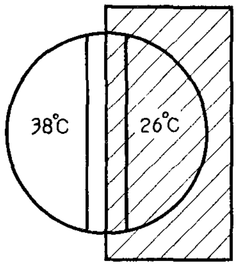
D: The dark side was held at a temperature lower than the optimum for *P. ulmi*, and the light side was held at a temperature higher than the optimum of this species.



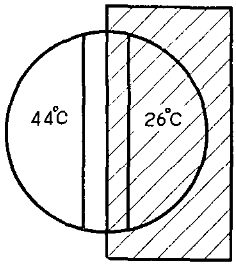
E: The dark side was held at a temperature higher than the optimum for *P. ulmi*, and the light side was held at the preference temperature of *P. ulmi*.



F: The dark side was held at a temperature lower than the optimum for *P. ulmi*, and the light side was held at the preference temperature.



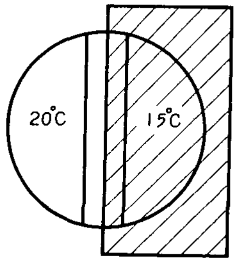
B′: The dark side was held at the preference temperature of *P. ulmi*, and the light side was held at a much higher temperature as compared with the light side in B.



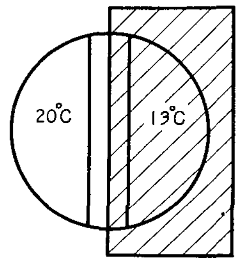
B″: The dark side was held at the preference temperature like B and B′. The dark side was held at a much higher temperature as compared with the light side in B′.

A different procedure was formulated for *T. telarius* owing to their specific character in thermal reaction in which they show no distinguished temperature preference. That is, the experiments were caried out according to the following schemata (G, G′, H, I and I′).

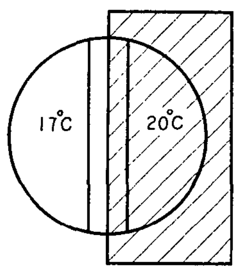
Experiments I and I′ were made in order to prove the terminal point of higher temperature at which the higher photo-kinesis of mites was reduced.



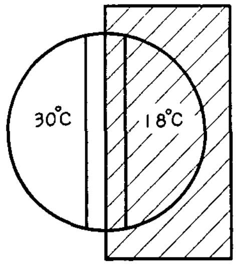
G: The light side was held at 20°C., and the dark side was held at 15°C.



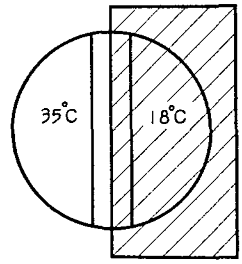
G′: The light side was held at the same temperature as in G, and the dark side was held at 13°C.



H : The dark side was held at 20°C. this time, and the light side was held at a temperature slightly lower than the opposite side.



I: The dark side was held at 18°C., and the light side was held at 30°C.



I′: The dark side was held at 18°C., and the light side was held at a much higher temperature than the light side in I.

PHOTO-KINESIS OF SPIDER MITES IN ALTERNATIVE CHAMBER

As the phototaxis of the spider mites has already been reported in a previous paper (Mori 1962), the photo-kinesis of the mites will be discussed in this paper.

A hood of black paper was put on a half of the upper-central vessel in the "temperature alternative chamber" so as to form an alternative chamber in respect to light. The temperature of each side of the alternative chamber should be kept constant in this experiment. The behaviour of *T. viennensis* was examined under two conditions of illumination; that is, in one case the

TABLE 1 (A). In the case of illumination by 60 watts bulb

Observation	Time elapsed after beginning of experiment (min.)	Number on light side (Temperature held at 27°C.)	Number on intermediate zone	Number on dark side (Temperature held at 27°C.)
—	0	—	26	—
I	10	15	8	3
II	20	11	11	4
III	30	15	10	1
IV	40	14	10	2
V	50	14	11	1
VI	60	13	11	2
Total		82	87	13

TABLE 1 (B). In the case of illumination by 20 watts bulb

Observation	Time elapsed after beginning of experiment (min.)	Number on light side (Temperature held at 27°C.)	Number on intermediate zone	Number on dark side (Temperature held at 27°C.)
—	0	—	18	—
I	10	6	6	6
II	20	6	5	7
III	30	7	6	5
IV	40	8	4	6
V	50	8	6	4
VI	60	5	7	6
Total		40	52	34

arena was lighted from the right at 45 cm above by a "mazda" lamp of 20 watts, 100 volts, and in the other case it was lit from the same distance by the lamp of 60 watts, 100 volts. The number of mites dispersed on the light and on the dark side and on the intermediate zone was counted six times (Table 1). The intensity of reaction was expressed by the proportion of the number of mites scattered in the light side to those of the dark side.

As can be seen from these data in the case of illumination by 60 watts bulb, there was difference in the number of congregated mites between the light and dark sides (the intensity of reaction was 6.3). However, in the case of illumination by 20 watts bulb, the mites were distributed evenly on the arena (the intensity of reaction was 1.2). In the former the mites showed a distinct photo-klinokinesis while in the latter such reaction was not recognized.

REACTIONS OF SPIDER MITES TO COMBINATIONS OF LIGHT AND TEMPERATURE

Panonychus ulmi

As shown in Table 2 (in experiments A and B) the mites were found to be more abundant on the light side though the dark side was held at their preference temperature. However, in experiment B the greatest number of mites were found on the intermediate zone. In experiment C, they swarmed in the light side at 20°C. The mites scarcely entered the dark side at 33°C.,

TABLE 2. Reactions of ***P. ulmi*** to combinations of light and temperature

Experiment	Number of mites	Total * recordings	Number on light side	Number on intermediate zone	Number on dark side	Preferred side	Intensity of reaction
A	18	126	66	45	15	Light	4.4
B	20	140	58	66	16	Light	3.6
C	17	119	77	40	2	Light	39.0
D	15	105	16	54	35	Dark	2.2
E	20	140	80	44	16	Light	5.0
F	22	154	69	37	48	Light	1.4
B′	15	105	39	28	38	—	1.0
B″	15	105	54	43	8	Dark	6.8

* Total of mites which were recorded seven times.

the intensity of reaction amounting to 39.0. The tracks of the mites were convoluted over the light side showing a distinct photo-klinokinesis. In experiment D in which the combinations of shading and temperature treatment were the reverse of those in experiment C, the mites were found more abundant in number on the dark side than on the light side. This came from the fact that several mites came to a standstill on the dark side at 20°C. However, in this case a half of the mites were distributed on the intermediate zone. In experiment E in which the light side was held at the preference temperature of this species, the mites preferred to stay on the light side. The number of mites distributed over the light side at each time of observation was found greatest. In experiment F, the light side was also held at their preference temperature. Though the mites were found to be abundant on the light side, the intensity of reaction was merely 1.4. In this case the mites become very sluggish and stopped moving on several occasions in the darkness at 20°C.

From the above series of experiments it is clear that the temperature preference of *P. ulmi* is disturbed by their photo-klinokinesis. Namely, the mites are more susceptible to the light-stimulus than to temperature.

When the light side was held at 38°C. and the dark side at 26°C. as in experiment B′, the mites were evenly distributed on both sides. In experiment B″, the mites swarmed to the dark side and a sharp avoidance reaction took place on the light side at 44°C. It may be said from the data of experiments B, B′ and B″ that the tendency of photokinesis of this species was reduced by any grade of temperature above 38°C.

Bryobia praetiosa

As can be seen from Table 3, the mites usually prefer the light side. In experiment A, they preferred the light side at 18°C. rather than the dark side

TABLE 3. Reactions of *B. praetiosa* to combinations of light and temperature

Experiment	Number of mites	Total * recordings	Number on light side	Number on intermediate zone	Number on dark side	Preferred side	Intensity of reaction
A	10	70	25	43	2	Light	12.5
B	10	70	22	48	0	Light	—
C	10	70	27	43	0	Light	—
E	14	98	43	49	6	Light	7.2
F	12	84	43	39	2	Light	21.5

* Total of mites which were recorded seven times.

even though it was held at their preference temperature. Though a larger number of mites remained in the intermediate zone than in the lit, cooler side, they scarcely entered into the dark side. It is remarkable in experiment B that no mites were found in the dark side though they were held at their preference temperature as in experiment A. Also in experiment C, no mites were found in the dark side. On the contrary they swarmed into the light side on account of their intensive photo-klinokinesis : accordingly the intensity of reaction numerically amounted to infinity. In two experiments, B and C, the mites were found more abundant on the intermediate zone than on the warmer or cooler side which was illuminated. In experiment E the mites preferred to stay in the light side which was held at their preference temperature. In this case, the majority of mites in the light side were found motionless. In experiment F, they showed a strong preference for the light side with an intensity of 21.5. They entered only rarely into the dark side.

It has became clear from these experiments that the temperature-preferendum of *B. praetiosa* is disturbed severely by their photo-klinokinesis. Comparing *B. praetiosa* and *P. ulmi* it is seen that the intensity of reaction in the former is higher than in the latter. Consequently, in *B. praetiosa* the influence of photo-stimulus on thermo-reaction is stronger than that in *P. ulmi*.

Tetranychus viennensis

From experiments A and B it is seen that the action of photo-stimulus on the behaviour of this species is stronger than that of thermo-stimulus. In experiment A, the mites were found abundant in the light side as they were prevented by photo-stimulus from swarming into the dark side although it was held at their preference temperature. However, the majority of mites were

TABLE 4. Reactions of *T. viennensis* to combinations of light and temperature

Experiment	Number of mites	Total * recordings	Number on light side	Number on intermediate zone	Number on dark side	Preferred side	Intensity of reaction
A	13	91	34	52	5	Light	6.8
B	12	84	35	30	19	Light	1.8
C	13	91	57	26	8	Light	7.1
D	12	84	20	26	38	Dark	1.9
B′	13	91	6	34	51	Dark	8.5

* Total of mites which were recorded seven times.

found in the lighter part of the intermediate zone. Though the dark side was held at the preference temperature in experiment B as well as in experiment A, they preferred the light side over the dark side. They also preferred the light side at 18°C. with the intensity of 7.1 in experiment C. A distinct photo-klinokinesis was shown in the light side. In experiment D, though the light side was held at 33°C., the mites were found more abundant in the dark side, having become increasingly sluggish and frequently inert on the dark side which was held at 17°C.

Looking over these data, one can see that the susceptivity of *T. viennensis* to light stimulus was stronger than that to temperature as was also the case in the former two species.

Experiments were made next in order to determine the grade of high temperature at mites lose their distinct photokinesis. It may be said from experiments B and B' that the high photokinesis of this species was reduced at about 38°C.

Tetranychus telarius

In experiment G, the mites were found abundant in the light side as they were prevented from swarming into the cooler side. It is evident that photo-stimulus attracts the mite more strongly than thermo-stimulus.

When the temperature of the dark side was lowered to 13°C. (experiment G'), most individuals stayed longer on the dark side. Under these conditions the

TABLE 5. Reactions of *T. telarius* to combinations of light and temperature

Experiment	Number of mites	Total * recordings	Number on light side	Number on intermediate zone	Number on dark side	Preferred side	Intensity of reaction
G	10	50	20	20	10	Light	2.0
G'	12	60	11	13	36	Dark	3.3
H	10	50	36	11	3	Light	12.0
I	9	45	14	14	17	—	1.2
I'	14	70	8	9	53	Dark	6.6

* Total of mites which were recorded five times.

intensity of reaction was 3.3. In this case no judgement can be made as to the effect of photo-stimulus which affects the behaviour of mites, because they become inert below 13°C. Of course, the mites swarmed to the light side kept at 17°C. in experiment H. The intensity of reaction reached 12.0, and a photo-klinokinesis was recognized.

According to the observations in experiment I, the mites were distributed evenly in the arena. This fact shows that the attractive power of photo-stimulus is weakened at about 30°C. In experiment I', the mites swarmed into the dark side. They scarcely entered the light side which was held at 35°C. and a distinct avoiding reaction appeared in this side. That is to say, their avoiding reaction to higher temperature (which happened at about 35°C.) surpassed the photokinesis of the mite.

From these facts, it may be said that in *T. telarius* the attraction of photo-stimulus is stronger than any temperature within the limits of 15°C. to 30°C. However, the high ptotokinesis in this mite is reduced at about 35°C. and the mite avoids remaining in too-warm places, even if it is lit.

SUMMARY

Four species of spider mites were tested for their behaviours under various combinations of thermal and light stimuli. The temperature preference of each species of mites is disturbed by their photo-klinokinesis. In other words, the mites are more susceptible to the light-stimulus than to the temperature. However, the tendency of photokinesis of the mites is reduced as high temperature as above 38°C. In the case of *T. telarius*, the attraction of photo-stimulus is stronger than that of temperature within the limits of 15°C. to 30°C. The high photokinesis of this mite is reduced at about 35°C.

The author wishes to express deepest appreciation to Prof. TETSUO INUKAI of the Faculty of Agriculture, Hokkaido University, for his valuable advice and encouragement.

LITERATURE

MORI, H. (1961): Comparative studies of thermal reaction in four species of spider mites (Acarina: Tetranychidae). J. Fac. Agric. Hokkaido Univ. 51, 574–591.

MORI, H. (1962): Seasonal difference of phototactic response in three species of spider mites (Acarina: Tetranychidae). J. Fac. Agric. Hokkaido Univ. 52, 1–9.