COMPARATIVE STUDIES OF THERMAL REACTION IN FOUR SPECIES OF SPIDER MITES (ACARINA: TETRANYCHIDAE)

By

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The feature of the thermal reaction of mites will serve to aid in a solution of problems concerning the forecast of the occurrence of mites or their seasonal prevalence.

Many papers have been published concerning the reaction of several insects to slowly rising or descending temperature and the temperature preference of some insects as well.

In Tetranychidae, the temperature preference of the adult of *Metatetranychus ulmi* (*Panonychus ulmi*) has been already discussed by the author (MORI 1953).

Before going further, the author wishes to express his sincere thanks to Professor Tetsuo INUKAI for helpful guidance given during the course of the present work, and for his kindness in reading through the original manuscript.

Temperature limit of activity

The four species of spider mites, *Panonychus ulmi* (KOCH), *Tetranychus viennensis* ZACHER, *T. telarius* (LINNAEUS) and *Bryobia praetiosa* KOCH, were collected from the apple trees in the orchards of Hokkaido University during the season from May to August, 1959. The mites were reared on potted apple trees in the laboratory for one day (temperature range between 26°C. and 29°C.). After that they were employed for the experiments.

To determine the temperature limit of the mites, the apparatus illustrated in Fig. 1 was used. The principle used by MACFIE (1920), WRIGHT (1927), KATO (1938) and others was applied for this experiment. The mites were placed in a glass tube of 12 cm. height and 3.3 cm. diameter stoppered with a cork;

the bulb of a thermometer was inserted through the cork. A little hole of 0.4 cm. diameter was bored in the cork for ventilation. A needle of 5.4 cm. length was stuck in the inner side of the cork, and a square paper (1.5 × 1.5 cm.) was set horizontally to the end of the needle (In Fig. 1, the arrow shows the square paper).

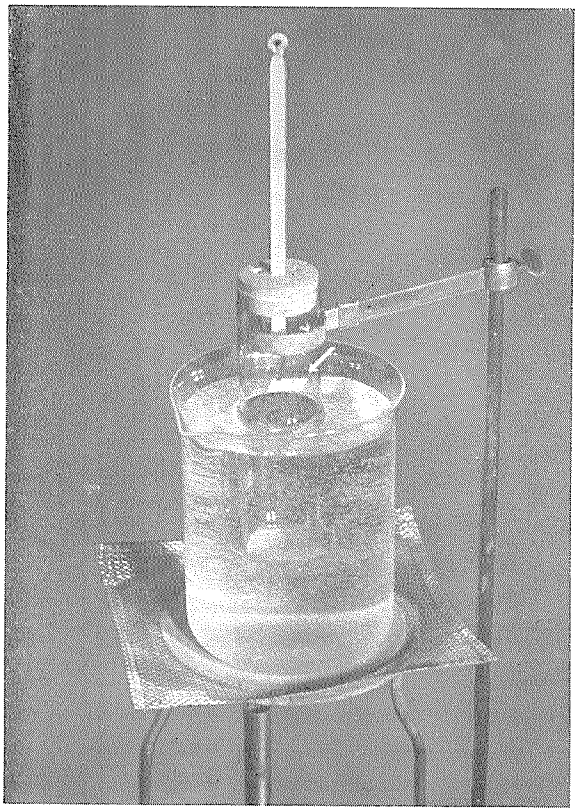

Fig. 1. Apparatus of thermal reaction.

Five or six mites were put on that paper in the glass tube, and tangle-foot (adhesive) was applied to the needle to prevent their escape from the paper. Next, this glass tube was soaked in a beaker (500 c.c. capacity) filled with ice water in order to regulate the temperature in the glass tube. The air temperature in the glass tube was first lowered to 2°C., and then allowed to rise at the rate of 1°C. every 4 minutes.

Many experiments have been done by other researchers concerning the temperature limit of activity of various insects (CHAPMAN et al. 1926, BODENHEIMER & KLEIN 1930, MOTOMURA 1936, KATO 1938, HUKUSHIMA 1954;

etc.). From the results reported by these researchers, it may be summarized that each insect living in different environments, has its own characteristic minimum and maximum temperature limits of activity.

When the temperature was gradually lowering, the activity of mites became weaker and weaker until at last they remain in an enervated stupor. Then the air temperature in the glass tube was raised gradually at the rate of 1°C. per 4 minutes as above mentioned. When the temperature in the tube was continually elevated, various changes in activity of the mites were observed.

In the present investigation various stages of activity of the mites were assumed according to the behaviour as discussed below.

Stage A: At first slight movement is observed in the legs or in the pedipalps of each individual.

Stage B: Locomotion starts in each mite. Sluggish activity or crawling.

Stage C: The normal walking begins to appear in each individual. Rather quick action, walking about the length of the arena (the square paper of 1.5 × 1.5 cm.). Walking speed was measured for comparison with stage D.

Stage D: Each mite shows a very strong activity and speed of locomotion is apparently greater than that of stage C.

Stage E: The mite becomes very sluggish or devitalized by heat paralysis, and at least falls into a state of heat coma.

Stage F: Death by heat. Life or death is determined by the test whether they can revive from the heat stupor when transfered to a moderate temperature. Each individual becomes blackened as soon as death takes place.

The observation was made with each test mite by recording the temperature at wich movement was commenced. The temperature range causing the movement was determined by the frequency distribution of 35 individuals.

The results obtained from the present investigation using species of mites are tabulated in Table 1 and illustrated in Fig. 2.

According to these observations, the starting temperature limits of the several stages vary with species and sexes. From Table 1, it can be seen that the temperature limit of A-stage in which the mite begins to stir coming round from cold stupor, ranges from 4.8°C. to 18.5°C.

Speaking of stage A, *T. viennensis* shows the characteristic movement in temperature higher than that of any other species. On the contrary, The male of *T. telarius* shows it in temperature as low as 5.8–7.5°C.

It is apparent that the starting limits of A and B-stage are often overlaped with each other. It fact, some mites do not come out of cold stupor while the others are already walking. The same is true for each species, some mite starting the normal movement without having gone through B-stage.

TABLE 1. Temperature ranges in which various stages of activity are shown.

(Confidence coefficient: 95%)

Species name	Sex	Phases of activity					
		A-stage	B-stage	C-stage	D-stage	E-stage	F-stage
Panonychus ulmi	Female	4.8- 9.8	5.0-15.7	16.0-21.8	30.0-33.8	41.0-43.0	44.0-47.0
	Male	7.3-11.8	9.0-16.2	14.5-20.7	30.7-32.0	41.5-42.8	44.0-45.5
Tetranychus viennensis	Female	9.2-18.5	14.8-19.2	16.0-23.0	32.8-33.5	40.8-44.2	43.5-45.0
	Male	12.8-14.5	13.0-16.8	20.0-23.5	34.0	39.0-40.0	41.0-44.5
Tetranychus telarius	Female	6.7-13.0	8.8-13.0	12.5-14.5	30.0-32.5	43.8-44.0	45.0-46.0
	Male	5.8- 7.5	7.0- 7.5	13.5-15.5	31.0-33.0	46.0-47.5	47.0-47.8
Bryobia praetiosa	Female	6.0-14.0	10.8-14.5	15.5-19.8	29.8-35.0	40.2-45.0	45.0-46.5

* Up to date the male of *B. praetiosa* is unknown.

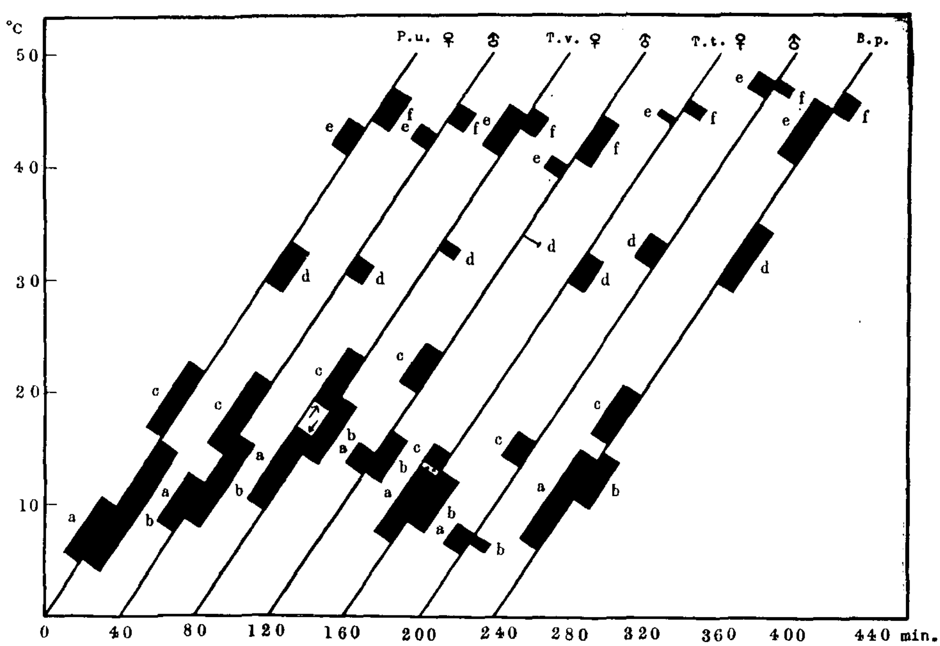

Fig. 2. Temperature ranges causing various stages of activity of mites.

In stage B the mite wriggles or moves sluggishly within a small limited place on or sometimes under the arena. In stage C it travels along the edge of the paper usually at a brisk pace. *T. telarius* starts normal walking at the lowest temperature, viz. from 12.5°C. to 15.5°C. However, *T. viennensis* does not commence movement until the temperature rises from 16.0°C. to 23.5°C.

The average velocity of locomotion under these conditions is as follows: The female of *T. viennensis* moves 0.188 cm./sec. at 26°C., while the male showes 0.195 cm./sec. at the same temperature. In the case of *T. telarius* the locomotion velocity at 24°C. is 0.079 cm./sec. in the female and 0.082 cm./sec. in the male.

The activity of the mites increases gradually in accordance with the temperature rise, and they become excited at above a certain temperature. The beginnings of the movement of stage D in four species were observed ranging 29.8°C. to 35.0°C. The degree of the excitement of the mite can be estimated by careful observation on their intensity of locomotion. The locomotion velocity of the mite increases remarkably, viz. *T. viennensis* moves at 0.536 cm./sec. at 33°C. in the female and 0.395 cm./sec. at 35°C. in the male. In stage D, only a few mites went over the edge to the opposite side of the paper. Many of them move about in confusion on the paper.

When the temperature rises continually, the mite falls finally into the state of heat paralysis. Stage E starts generally at about 40°C., but in the male of *T. viennensis* the paralysis occurs at the temperature between 39.0°C. and 40.0°C. *T. telarius* enters stage E at the temperature higher than other species, especially in the case of the male it is 46.0–47.5°C.

At about 41°C., many individuals of *T. viennensis* die. For other species the fatal temperature is higher ranging from 44°C. to 47°C. The males of *T. telarius* die at 47.0–47.8°C.

It is interesting to compare the thermal reation of the mite with that of insects which inhabit the apple orchards. Table 2 shows the temperature limits of activity of several harmful insects in the apple orchards in Japan as reported by HUKUSHIMA (1954). His experiments were carried out under the changing temperature which rose at the rate of 1°C. every 3 minutes.

As indicated in the next table, activity is controlled by the temperature and the limits of activity in various stages vary according to the species of insects. However, in comparison of the author's four species of mites with the next nine insect species concerning the temperature limits of activities, there is no remarkable difference between them except for *T. telarius*. In the latter, normal walking is observed beginning at a lower temperature than in the other mites or insects.

TABLE 2. Temperature ranges of activity of several insects (HUKUSHIMA 1954).

Species name		Phase of activity									
		Cold stupor	Slight movement	Keeping the body in normal position	Crawling or walking	Flying	Strong activity	Excitement	Falling down or keeping the body in abnormal position	Heat stupor	Death
Cacoecia crataegana	Adult	2.5–6.5	10.3–14.7	18.0	23.1–27.9	24.8–29.2	—	34.9–39.1	—	39.5–44.5	42.5–47.5
	Larva	0.3–3.9	6.0 10.0	11.4–15.6	18.3–22.7	—	26.5–30.5	32.5–36.5	37.4–41.6	41.4–45.6	42.5–47.5
Cacoecia xylosteana	Adult	0.7–4.3	6.9–11.1	11.5–16.5	17.0–21.0	—	25.3–29.7	33.0–37.0	37.1–41.6	39.5–44.5	42.5–47.5
	Larva	0.3–4.1	5.0– 9.0	—	13.3–17.7	—	23.9–28.1	32.0–36.0	—	38.0–42.0	41.4–46.5
Carposina niponensis	Adult	2.4–6.6	8.4–12.6	12.4–16.6	20.2–24.8	21.3–25.7	—	29.0–33.0	34.5–38.5	39.4–43.6	42.5–47.5
	Larva	1.4–5.6	11.0–16.0	—	23.4–27.6	—	—	33.7–38.4	—	41.5–46.5	43.5–48.5
Coleophora malivorella	Adult	1.2–3.4	7.9–12.2	12.4–16.6	18.1–23.0	19.4–23.6	29.4–33.6	36.0–40.0	38.0–42.0	41.4–45.6	44.4–48.6
	Larva	3.3–7.4	12.5–16.5	—	19.9–24.1	—	27.6–31.5	34.4–38.5	—	42.5–46.5	47.4–52.6
Lithocolletis ringoniella	Adult	1.0–5.0	6.8–11.2	13.5–18.5	21.6–26.4	—	—	32.0–36.0	35.5–40.5	39.4–43.5	42.5–47.5
	Larva	2.0–6.0	8.4–12.5	—	20.0–25.0	—	—	33.8–38.2	—	39.5–44.5	43.4–47.6
Orgyia thyellina	Adult	2.1–7.9	6.0– 9.0	10.1–13.9	15.5–19.5	25.5–30.5	—	36.4–40.6	40.5–45.5	42.5–47.5	45.5–50.5
	Larva	3.4–5.5	5.1– 8.9	—	13.1–18.9	—	25.6–30.4	35.0–39.0	—	41.4–45.5	46.5–51.5
Pandemis heparana	Adult	1.6–4.5	9.0–13.0	13.5–18.5	20.3–24.7	27.9–32.1	—	35.0–39.0	—	39.4–43.6	42.5–47.5
	Larva	0.6–5.6	6.4–11.3	—	17.1–21.9	—	28.5–32.5	34.4–38.5	—	39.0–43.0	42.5–47.5
Rhamphus pulicarius	Adult	1.4–5.6	7.0–11.0	10.5–15.5	18.2–22.8	—	28.0–32.0	36.8–41.2	—	—	43.5–48.5
Spilonota ocellana	Adult	2.0–6.0	9.4–13.5	15.4–19.6	24.1–28.9	24.6–29.4	—	34.5–38.5	37.5–42.5	39.5–44.5	44.5–47.5
	Larva	2.1–6.6	9.0–13.0	13.5–18.5	19.4–23.6	—	27.0–31.0	33.5–37.5	38.4–42.6	41.5–46.5	43.5–48.5

It may be said that the temperature zone of activity of the mite can be measured from the difference between B-stage and E-stage.* According to the present investigation, the temperature zone of activity of each species is seen in Table 3.

The temperature zone of activity of above-mentioned insects in apple orchards can be found in Table 2.

TABLE 3. Temperature zone of activity of several mites and insects which occur on the apple tree.

Species name	Sex or developmental stage	Temperature (°C.)	Range (°C.)
Panonychus ulmi	Female	5.0—41.0	36.0
	Male	9.0—41.5	32.5
Tetranychus viennensis	Female	14.8—40.8	26.0
	Male	13.0—39.0	26.0
Tetranychus telarius	Female	8.8—43.8	35.0
	Male	7.0—46.0	39.0
Bryobia praetiosa	Female	10.8—40.2	29.4
Cacoecia crataegana	Adult	23.1—39.5	16.4
	Larva	18.3—41.4	23.1
Cacoecia xylosteana	Adult	17.0—39.5	22.5
	Larva	13.3—38.0	24.7
Pandemis heparana	Adult	20.3—39.4	19.1
	Larva	17.1—39.0	21.9
Spilonota ocellana	Adult	24.1—39.5	15.4
	Larva	19.4—41.5	22.1
Carposina niponensis	Adult	20.2—39.4	19.2
	Larva	23.4—41.5	18.1
Coleophora malivorella	Adult	18.1—41.4	23.3
	Larva	19.9—42.5	22.6
Lithocolletis ringoniella	Adult	21.6—39.4	17.8
	Larva	20.0—39.5	19.5
Orgyia thyellina	Adult	15.5—42.5	28.3
	Larva	13.1—41.4	27.0
Phamphus pulicarius	Adult	———	(23.0)

* For this purpose, the temperature difference is obtained by subtracting the lowest temperature value in B-stage from that in E-stage.

As shown in Table 3, the temperature zones of activity for *P. ulmi* and *T. telarius* are considerably wider than those of *T. viennensis* and *B. praetiosa*. Particularly, in the former two species, the ranges of activity were observed extending toward lower temperature. No difference was found to exist in the activity zone between the female and the male of the mites. In the case of several insects which were investigated by HUKUSHIMA, the temperature ranges are very variable according to the species. The zone of the larva was wider than that of the adult with the exception of a few species.

It may be generalized that the temperature zones of activity for the mites are wider than those for the insects. However, one species of insect, viz. *Orgyia thyellina*, has more or less similar zone of activity to that of *T. viennensis*.

Temperature preference

The temperature preference of insects has been studied by many authors exposing them to a wide temperature gradient employing various forms of apparatus (HERTER 1924, NIESCHULTZ 1933, MARTINI & TEUBNER 1933, HOMP 1938 etc.). Many researchers have usually used "Temperaturorgel (Verbesserte Temperaturorgel)" devised by HERTER (1923, '24, '36), and others used a modification of that apparatus. One of the insurmountable drawbacks of these types of apparatus is that the temperature is not the only variable factor. Wherever there is a temperature gradient, a gradient of relative humidity and saturation deficiency must be taken into consideration.

In the present investigation a temperature gradient apparatus (temperature alternative chamber) which was devised by THOMSON (1938) for the study of the reactions of mosquitoes to temperature was used. This method has been employed also for studying temperature responses in the human louse (WIGGLESWORTH 1941). The structure and operation of the alternative chamber is superior to other types since its temperature can be regulated without restraining the humidity gradient which is caused necessarily by the gradient of temperature.

The apparatus consists of two semicircular cylinders 40 cm. in diameter and 20 cm. in height made of galvanized iron sheet. These two semicircular cylinders are set to make a circle standing face to face 4 cm. apart from each other.

There is a semicircular dent on the upper part of the semicircular cylinders. In the dent is set a cylindrical dish of galvanized iron sheet with 16 cm. external diameter and 5 cm. depth. Warming one side while cooling the other side of this cylindrical dish the temperature alternative chamber is obtained.

In order to keep the alternative chamber unaffected by outside influence, it is covered with a double cover consisting of two plates of glass which have

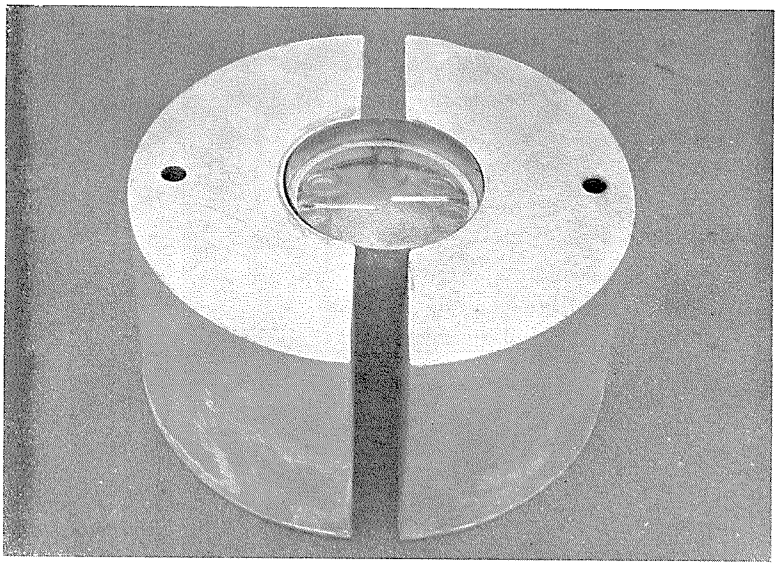

Fig. 3. Alternative chamber.

between them an insulating air space of about 5 mm. The mites are introduced into the chamber through a central hole of about 1 cm. diameter in the cover. The alternative chamber is rendered air-tight by the use of vaseline for the joint with the cover. Naturally the hole is closed with a cover slide glass after the introduction. Small dishes containing saturated solution of KNO_3 for the control of humidity are put on the bottom of the chamber and a sheet of victoria lawn with wire support is set upon the dishes. There is a space of 3 cm. between the sheet and the cover. At the edge of the sheet tangle-foot (adhesive) is applied to prevent the escape of mites from the arena.

When the apparatus is in use both semicircular vessels are filled with water. In each vessel the water is heated or cooled as required. For heating, a carbon filament lamp is used and for cooling running tapwater or ice is used. During the experiment the temperature difference between the two sides in the alternative chamber was recorded by two small thermometers which were set on the sheet 3 mm. distant from the wall.

For the protection of the whole apparatus from outside temperature it was buried in a big wooden box stuffed with sawdust except the uppersurface of the alternative chamber which was left unprotected for observation. For uniform lightning an electric lamp (60 Watt 100 Volt) was used at 45 cm. above the apparatus.

For experiments four species of spider mites, namely *P. ulmi*, *B. praetiosa*, *T. telarius* and *T. viennensis* were used. Samples were collected from apple trees in Sapporo from May to October, 1959. The mites were used for experiments after they had been kept in the laboratory for more than one day. The first series of experiments was carried out as follows: 7 to 25 mites were put in the apparatus, and the number of mites on each side (cool side and warm side) of the chamber was counted during 35 minutes at intervals of 5 minutes. The number of mites which remained in the intermediate zone along the mid-line of 4 cm. width between the different temperature sides was omitted.

The females of *Panonychus ulmi*

At first the reaction of the mites to the difference of temperature was investigated by exposing them to 5°C. difference at different parts of the temperature scale. In a 30–35°C. gradient the mites showed a strong avoidance of high temperature. The intensity of reaction is expressed by the proportion of the number of mites in the cooler side and warmer side. In this case the proportion was 7.2.

When the temperature decreased and the gradient showed 25–30°C. more mites were found in the cooler side than in the warmer side. In 20–25°C. gradient and in 15–20°C. avoiding reaction appeard. In those gradients the mites were found abundant in number in the warm side and when disturbed they swarmed into the cooler side. The intensity of reaction was 3.1 and 6.2 respectively. In 10–15°C. gradient they showed no preference. Generally, below 10°C. the mites become very sluggish and showed no response to the temperature difference of 5°C.

When the gradient was narrowed by 2°C. as in the series of 28–30°C. and 23–25°C., the intensity of reaction was 2.6 in the former and 1.6 in the latter. However, when the gradient was kept long at 26–28°C. and 25–27°C. the mites were evenly distributed in two sides. It has become clear that the female of this species react strongly to the difference of 2°C. at temperatures higher than 28°C. or lower than 23°C., while they show no preference at temperatures between 25°C. and 28°C. for the same difference.

In the second series of experiments, the temperature on one side was kept constantly at 25°C., while the other side was regulated to various temperatures, namely 40°C., 35°C., 30°C., 27°C., 20°C. and 15°C. respectively.

The mites were introduced one by one into the chamber and their movement was traced for 30 minutes by means of the tracks recorded on the paper that was prepared beforehand.

In each case the mites were active and showed a high rate of random

TABLE 4. Temperature preference of the females of *P. ulmi*.

Temperature gradient (°C.)	Number of mites	Total of mites	Number of mites on warm side	Number of mites on cool side	Preferred side	Intensity of reaction
35–30	12	104	5	36	cool	7.2
30–25	12	108	21	35	cool	1.7
25–20	12	108	37	12	warm	3.1
20–15	12	96	31	5	warm	6.2
15–10	12	108	28	21	no pref.	1.3
30–28	23	161	32	83	cool	2.6
28–26	12	96	32	30	no pref.	1.1
27–25	25	175	57	48	no pref.	1.2
25–23	12	108	28	18	warm	1.6

turning in their track on the optimum side. Some individuals were indifferent to the temperature as high as 35°C., or as low as 20°C. These were exceptional; they showed mostly well-marked responses to the difference of temperature.

Fig. 4 shows some typical reactions of different individuals to several series of temperature gradients. In 25–40°C. gradient and 25–35°C. series a sharp avoiding reaction took place to the warm side. The mites turned back instantly to the opposite boundary of the warm side. In 25–20°C. gradient, their tracks were more convoluted in lower temperature side and they often turned towards the middle of the chamber.

When exposed to 15°C. they scarcely entered the cool zone. This means that the avoidance of low temperature is not very frequent. There was no preference of temperature in 25–27°C. series and a distinct klinokinesis was observed in both halves of the chamber.

The males of *Panonychus ulmi*

The behaviour of the males of this species does not much differ from that of the females. On exposure to a gradient of 35–30°C., they showed an intense avoidance of the higher temperature side. The intensity of reaction was 6.0. However, in 25–20°C. and in 20–15°C. gradients the intensity of avoidance of the low temperature side was 4.0 and 5.2 respectively.

In 15–10°C. gradient the males did not show any kind of discrimination. Below 15°C. the males become increasingly sluggish. When the difference was narrowed to 2°C., the avoidance of lower temperature was still evident. For example, in 25–23°C. series the mites were found more abundant on the warm

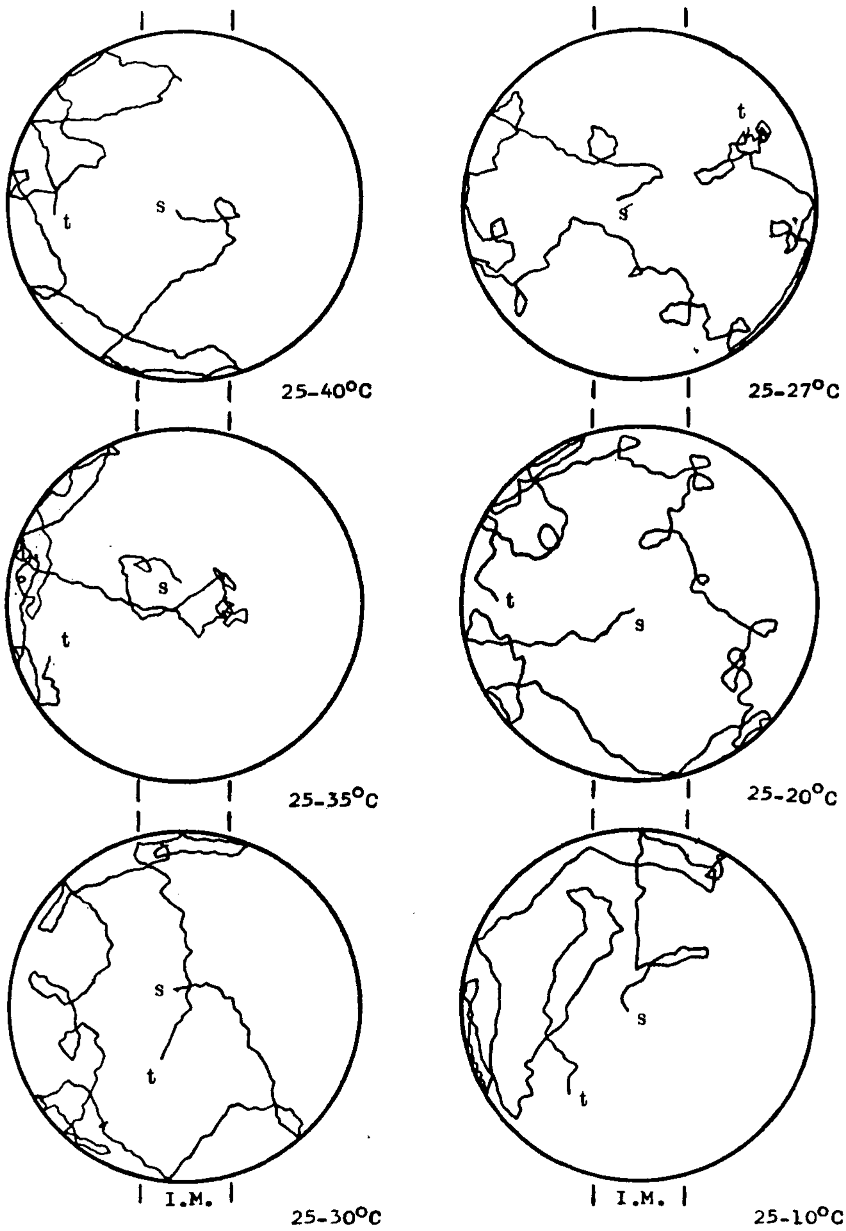

Fig. 4. Tracks of *Panonychus ulmi* when the temperature was the optimum in one side of the arena.

side. However, in 28–26°C. and in 27–25°C. gradients, there was no reaction to the difference of temperatures.

TABLE 5. Temperature preference of the males of *P. ulmi*.

Temperature gradient (°C.)	Number of mites	Total of mites	Number of mites on warm side	Number of mites on cool side	Preferred side	Intensity of reaction
35–30	12	84	5	30	cool	6.0
30–25	12	84	21	27	cool	1.3
25–20	12	84	32	8	warm	4.0
20–15	12	84	26	5	warm	5.2
15–10	12	84	17	22	no pref.	1.3
30–28	12	84	20	31	cool	1.6
28–25	12	84	27	28	no pref.	1.0
25–23	12	84	34	10	warm	3.4

The females of *Bryobia praetiosa*

When the mites were put in the chamber which has 5°C. gradient as in 35–30°C. and in 30–25°C. series, there occurred distinct avoidance of the higher temperature. The intensity of reaction varied from 7.5 to 9.0 and the tendency was stronger on the average than in *P. ulmi* at the same gradient.

TABLE 6. Temperature preference of *B. praetiosa*.

Temperature gradient (°C.)	Number of mites	Total of mites	Number of mites on warm side	Number of mites on cool side	Preferred side	Intensity of reaction
35–30	10	70	2	15	cool	7.5
30–25	9	63	3	27	cool	9.0
25–20	8	56	10	11	no pref.	1.1
20–15	7	49	22	4	warm	5.5
27–25	8	64	4	11	cool	2.8
25–23	8	72	12	20	cool	1.7
24–22	8	64	16	16	no pref.	1.0
23–21	8	56	11	9	no pref.	1.2
22–20	17	119	34	17	warm	3.4

When exposed to the gradient of 25–20°C., they were irresponsive to the difference of temperature. In 20–15°C. gradient the mites showed an avoidance of the lower temperature like *P. ulmi* did. However, some individuals became sluggish in the cooler side and then they remained for a long time on that side. Below 10°C. they settled anywhere and showed no response to temperature difference.

When the gradient was narrowed to 25–23°C. with the range of 2°C., the intensity of the reaction was reduced to 1.7. However, in two series, 24–22°C. and 23–21°C., there was no apparent avoiding reaction and the mites were evenly distributed. In 22–20°C. gradient they swarmed to the warmer side with an intensity of 3.4.

Fig. 5 shows the track of each mite in each temperature gradient. In this case the temperature in one side of the chamber was gradually lowered while the other side was kept at 23°C. constantly. In each case there occurred an exceeding turning and zigzag course on the optimum temperature side. On

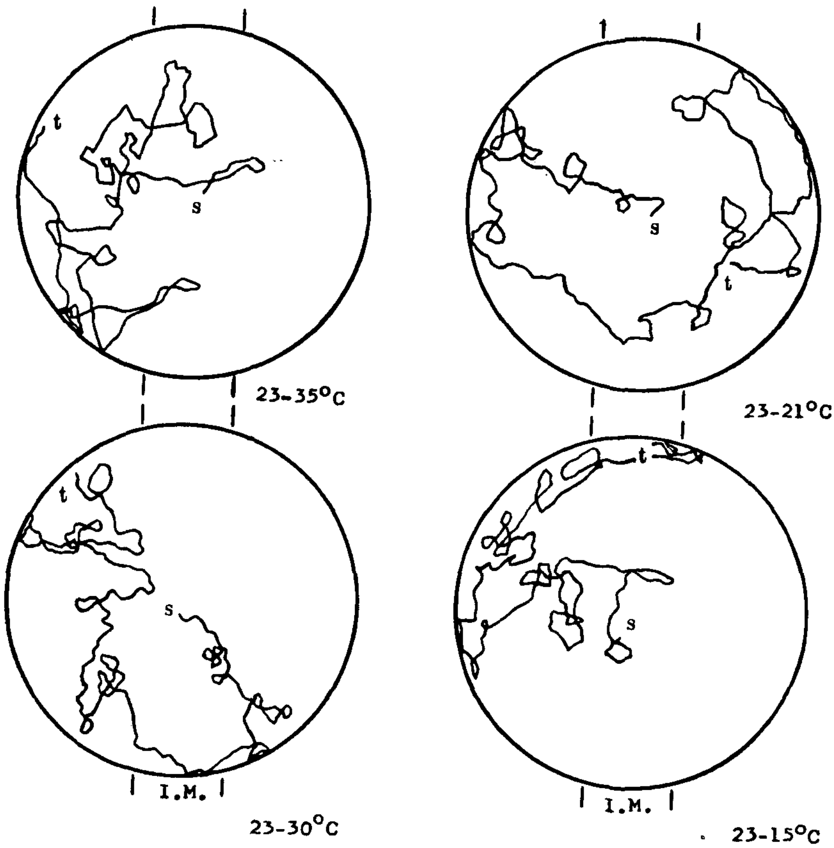

Fig. 5. Tracks of *Bryobia praetiosa* when the temperature was the optimum in one side of the arena.

passing into 35°C. the reaction was most pronounced and the mites turned back to the optimum side after going a very short distance. When exposed to gradient of 23–15°C. they scarcely entered into the cool side, thus showing distinct avoiding reaction in this side.

The females of *Tetranychus viennensis*

When exposed to gradient of 35–30°C., there was a weak avoidance of the higher temperature with an intensity of 1.4. The mites showed no preference when offered a choice between 30°C. and 25°C. In two series of 25–20°C. gradient and 20–15°C. gradient they were more abundant on the warm side. Some individuals become inert on 15°C. side. The intensity of reaction was 3.1 in the former and 2.3 in the latter. Generally below 18°C. they became increasingly sluggish, and below 12°C. a large majority of mites stand still in the cold.

TABLE 7. Temperature preference of the females of *T. viennensis*.

Temperature gradient (°C.)	Number of mites	Total of mites	Number of mites on warm side	Number of mites on cool side	Preferred side	Intensity of reaction
35–30	8	72	11	15	cool	1.4
30–25	10	70	19	19	no pref.	1.0
25–20	17	119	40	13	warm	3.1
20–15	16	112	21	9	warm	2.3
32–30	15	120	15	23	cool	1.5
30–28	20	160	34	34	no pref.	1.0
27–25	14	98	23	24	no pref.	1.0
25–23	15	120	34	23	warm	1.5

The next described experiments were carried out by exposing them to the difference of 2°C. In 32–30°C. gradient they abounded in number on the cool side. On the contrary in 25–23°C. one they abounded in number on the warm side. In the 30–28°C. and in 27–25°C. gradients, they did not show any noticeable reaction to the difference of temperature.

It is concluded from the present data that this species is less sensitive to the difference of temperature than *P. ulmi* and *B. praetiosa*.

The females of *Tetranychus telarius*

There is a significant feature in thermal reactions of this species, when exposed to the difference of 5°C. in the alternative chamber.

TABLE 8. Temperature preference of the females of *T. telarius*.

Temperature gradient (°C.)	Number of mites	Total of mites	Number of mites on warm side	Number of mites on cool side	Preferred side	Intensity of reaction
35–30	12	84	16	37	cool	2.3
30–25	15	105	22	41	cool	1.9
25–20	15	105	9	62	cool	6.9
20–15	14	98	22	50	cool	2.3
15–10	12	84	25	27	no pref.	1.1
15–13	15	105	12	40	cool	3.3

In each series of the following combinations, viz. 35–30°C., 30–25°C., 25–20°C., 20–15°C. gradients, the mites preferred to stay on the cooler side the intensity of reaction being 2.3, 1.9, 6.9 and 2.3 respectively. Under these circumstances most individuals stayed for longer time on the cooler side. As they pass into warmer side their track was more convoluted turning generally towards the adverse side after going a short distance. In 15–10°C. gradient there was no avoidance of the warm side and no preference for either the warm or the cool. They became very sluggish at 10°C. When the gradient was less than 2°C. as in series of 15–13°C., the intensity of avoidance of the higher temperature was practically unchanged, being 3.3.

The males of *Tetranychus telarius*

As shown in the next table, the thermal reactions of the males are very much like those of the females. In any of four gradient series, 35–30°C., 30–25°C., 25–20°C. and 20–15°C., the mites swarmed on the cooler sides without

TABLE 9. Temperature preference of the males of *T. telarius*.

Temperature gradient (°C.)	Number of mites	Total of mites	Number of mites on warm side	Number of mites on cool side	Preferred side	Intensity of reaction
35–30	12	84	13	39	cool	3.0
30–25	12	84	8	49	cool	6.1
25–20	12	84	2	42	cool	21.0
20–15	10	70	0	50	cool	50.0
15–10	12	84	24	23	no pref.	1.0
15–13	14	98	20	38	cool	1.9

exception. For example, in 30–25°C. gradient out of 84 females, 49, or 58 per cent., settled on the cooler side. The intensity of reaction was 6.1. In 20–15°C. gradient there was still strong preference for low temperature with an intensity of 50.0. They showed no preference in 15–10°C. gradient just like the females. However, when exposed to gradient of 15–13°C., with the range of 2°C., they preferred lower temperature with an intensity of 1.9. Below 10°C. they became inert, showing inclination neither to the warmer side nor to the cooler side.

Summary

The temperature ranges in various phases of activity of the spider mites varied between sexes and among each species (Fig. 1). The temperature zones of activity for *P. ulmi* (female, 5.0–41.0°C. male, 9.0–41.5°C.) and *T. telarius* (female, 8.8–43.8°C. male, 7.0–46.0°C.) are considerably wider than those of *T. viennensis* (female, 14.8–40.8°C. male, 13.0–39.0°C.) and *B. praetiosa* (female, 10.8–40.2°C.). No difference was found to exist in the activity zone between the female and the male of the spider mites.

For the measurement of the temperature preference in the spider mites the "alternative chamber" was employed. The temperature preference of each species occurred as the following: in *P. ulmi*, female and male for 25–28°C., in *B. praetiosa*, female for 21–24°C., in *T. viennensis*, female for 25–30°C., *T. telarius* usually prefers lower temperature within the range of 13–35°C.

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