The Ecological Studies on the Corn-linear Leaf-miner,

***Phytomyza nigra* MEIGEN. * (I)**

The Temperature Limit of Activity and the Diurnal Activity of the Corn-linear Leaf-miner.

By

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Introduction

The corn-linear leaf-miner, *Phytomyza nigra* MEIGEN, is one of the most important economic species in the corn field in Japan and infests the leaves of cultivated barley, wheat, rye and other many weeds of the family Gramineae. This species is widely distributed in Japan.

The flies emerge from their overwintering puparia early in the spring (at the end of March to the beginning of April). The eggs are usually deposited beneath the upper or lower epidermis near the top and near the margin of the leaf. Usually one or two eggs are found on a single leaf, but sometimes more than three eggs are found. As a general rule, the larva at first mines towards the base of the leaf, next turns towards the apical part of the leaf contrary to the above and extending again towards the base of the leaf. The mine is the linear type through its entire larval stage. The larvae pupate near the end of the mine and a pair of anterior spiracles of the pupa project on the surface of the leaf. The flies of the second generation emerge at the beginning to the middle of May. Therefore, they appear twice during the the growing period of the corn. In the autumn, the flies emerge again and oviposit on the weeds belongs to the family Gramineae.

The experiments concerning the temperature limit of activity of various insects have been done by many authors since CHAPMAN (1926). Recently, in Japan, many authors have also reported the temperature reactions concerning the various important insects damage the cultivated plants, for the purpose of the research of those ecological characters (KATO, 1938 & 1948; OZAKI and YAMASHITA, 1949; SHIBATSUJI, 1949; NAKATA, 1950; YAMASHITA, 1950 & 1952; FUKUSIMA, 1952). Also, it is very interesting

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and important to investigate the relation between the diurnal activity of the said fly in the field and its environmental meteorological conditions. In the present first report, the temperature limit of activity, the locomotive velocity and the diurnal activity of the fly are dealt with.

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Material and Methods

The flies of the second generation, which are reared in the thermostat regulated constantly at 20°C during all stages of the first generation, were used in this investigation. After the emergence, the female and male flies were lapped with the honey for a day.

1. The laboratory experiment on the temperature reaction of the flies was executed according to MOTOMURA's Method (1938). Two female or male flies were obtained in a glass tube which is 3 cm. in diameter and 12 cm. in length and a circular sheet of the wire net was placed at a height of 4 cm. above the bottom. When the temperature in the glass tube had fallen to 0°C, the flies became motionless and unable to stand. Then, the temperature was allowed to rise at the rate of 1°C every two minutes and the seven following conditions of activity were observed.

At first, the fly begins the slight movement of legs or antennae, then, it stands up on its feet and after a while, begins to walk and then begins to fly. As the temperature rises, the fly becomes excited and nervous from the heat, then it falls to the bottom from heat paralysis and finally it dies.

The experiment was carried out five times. At the same time, the temperature reactions of *Phytomyza atricornis* MEIGEN reared from the pea, *Pisum sativum* L. var. *arvense* POIR. and *P. ranunculi* SCHRANK reared from the garden ranunculus, *Ranunculus asiaticus* L. were also investigated.

2. An experiment similar to the one just mentioned was conducted with the purpose of examining quantitatively the degree of activity of the fly under the various temperatures. A section-paper (1 mm. square in graduation) 10 cm. by 4 cm., for measuring the distance of walking, was pasted perpendicularly in a glass (1.5 cm. in diameter, 12 cm. in length). The velocity at which the fly climbs up from the bottom, as an index of the locomotive velocity, was measured in this experiment.

3. The observation concerning the diurnal activity of the fly was carried out on 18th of May and 22nd of the same month, 1953 at a corn-field near the laboratory. A breeding box (26×26×38 cm.) with organdie-net covering three sides and the top

and a glass front for observation purposes, was placed in the field (Fig. 1). Three

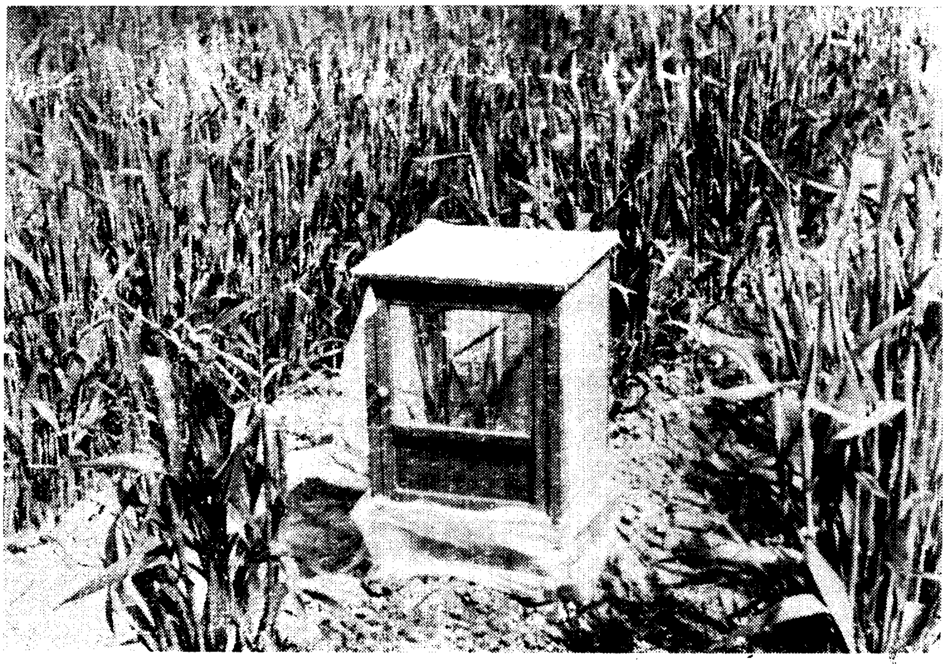

Fig. 1. The experimental breeding box palced in a barley-field.

barley plants (*Yanehadaka No.* 1 in Japanese) were planted inside of this box and three couples of flies were liberated into the box. Thus the activity of these flies was observed from 4.00 a.m. to 20.00 p.m. At the same time, the air temperature and the humidity in this box at height of 20 cm. from the ground and those at the upper zone of grass-growing were measured by ASMANN's Psychrometer. The wind-direction, wind-intensity and the amount of clouds were measured with the naked eye.

The locomotive velocity was also measured in this box by a similar method.

Results and Discussion

1) The Temperature Limit of Activity

The results are tabulated in Table 1. On the assumption that each temperature in the various conditions shows the normal distribution, the confidence limit of reliability 95 % was computed.

Table 1. Mean value of temperature at the various conditions of activity of the Corn-linear Leaf-miner.

Condition of activity	Flies	
	Female	Male
	°C	°C
Slight movement	4.43 ± 3.05	3.55 ± 2.51
Standing on feet	8.01 ± 2.95	5.48 ± 2.13
Walking	10.34 ± 2.97	9.27 ± 1.47
Flying	17.45 ± 2.24	17.70 ± 2.17

Nervous	31.80 ± 1.79	35.04 ± 1.45
Falling down (heat paralysis)	37.54 ± 2.16	37.70 ± 2.30
Death	40.88 ± 1.96	41.50 ± 3.40

According to these results, the first condition of activity of the fly, the slight movement, begins at about 4.5°C in female and 3.5°C in male and the last condition, the death, ends at about 41.0°C and 41.5°C respectively. The optimum zone of activity between the third to fifth condition is represented by the range from 10 to 32°C in female and from 9 to 35°C in male, that is, the width of this range is about 22.0 and about 26.0°C respectively. Therefore, the fly may be active in the range between these minimum and maximum effective temperature limits, but normal activity is not observed below 9°C nor above 35°C.

In comparing the female with the male, in the lower temperature zone from the condition of slight movement to walking, the female is less active than the male. On the contrary, in the higher temperature zone from the condition of flight to death, the former is more fatal than the latter. Accordingly, it may be easily understood from the fact that the range of the temperature zone of activity of the female is narrower than that of the male.

2) **Comparision of the Corn-linear Leaf-miner with a few other Leaf-miners**

The results of the experiments of the following three different species: the corn-linear leaf-miner, the chrysanthemum leaf-miner (*Phytomyza atricornis* MEIGEN) and the ranunculus leaf-miner (*P. ranunculi* SCHRANK), and those of other three authors related to the corn-blotch leaf-miner, *Agromyza albipennis* MEIGEN (YAMASHITA and others, 1952), the rice leaf-miner, *A. oryzae* MUNAKATA (syn. *oryzella* MATSUMURA)(KATO, 1948) and the soy-bean root-miner, *Ophiomyia* sp. (SHIBATSUJI, 1949) are shown in Fig. 2.

The temperature at which the fly of the corn-linear leaf-miner shows its first slight movement was somewhat higher than that related to the chrysanthemum leaf-miner, ranunculus leaf-miner and corn-blotch leaf-miner, and was distinctly lower than that to the rice leaf-miner and soy-bean root-miner. The lowest temperature at which movement occurred was 1.8°C as in the case of the male of the ranunculus leaf-miner and the highest was about 9°C as in the case of the soy-bean root-miner. The temperatures at which the corn-linear leaf-miner stood and walked showed the similar relationship to other leaf-miners. On the contrary, the temperature at which the said leaf-miner became nervous was lower than those related to the chrysanthemum leaf-miner, ranunculus leaf-miner and soy-bean root-miner and higher than those to the corn-blotch and rice leaf-miners. The temperatures at which the said leaf-miner fell down from heat paralysis and died were distinctly lower than those related to the

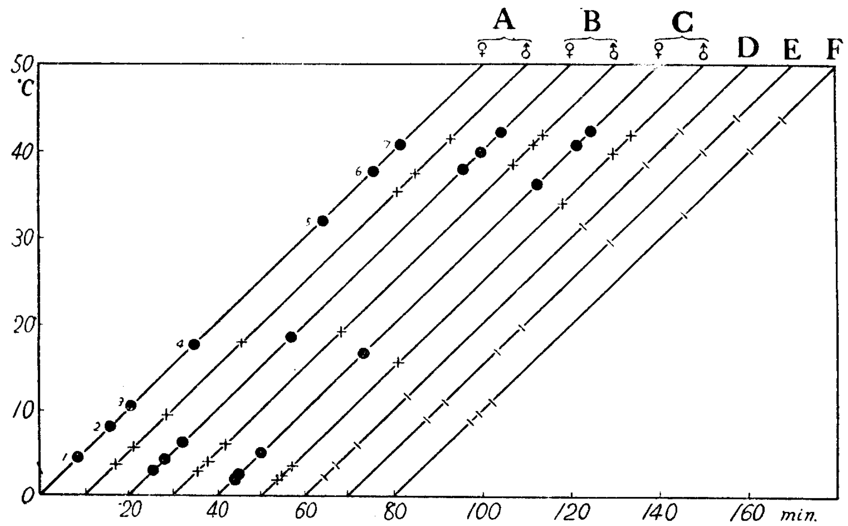

Fig. 2. The temperature limit of activity of six leaf-miners under the gradually rising temperature. The temperature shown in this figure is the mean temperature.

A: *Phytomyza nigra*; B: *P. atricornis*; C: *P. ranunculi*; D: *Agromyza albipennis*; E: *A. oryzae*; F: *Ophiomyia* sp.

1: Slight movement; 2: Standing on feet; 3: Walking; 4: Flying; 5: Nervous; 6: Falling down; 7: Death.

other five leaf-miners and a root-miner.

The optimum zone of activity of these leaf-miners may be easily measured from these results mentioned above. They are tabulated in Table 2.

Table 2. The optimum temperature zone of activity of the six leaf-miners

Species		Optimum zone of activity
Phytomyza nigra	♀	31.80° — 10.34° ≒ 22° C
	♂	35.04° — 9.27° ≒ 26° C
P. atricornis	♀	38.00° — 6.02° ≒ 32° C
	♂	38.50° — 5.90° ≒ 33° C
P. ranunculi	♀	36.33° — 4.90° ≒ 31° C
	♂	34.00° — 3.40° ≒ 31° C
Agromyza albipennis		31.80 — 7.00° ≒ 25° C
A. oryzae		29.63° — 16.72° ≒ 13° C
Ophiomyia sp.		32.00° — 11.00° ≒ 21° C

Kato (1948) reported that the rice leaf-miner is adaptable to a fairly low temperature environment as a result of his experiments. According to my results, it may be conceivable that the five leaf-miners are adaptable to a lower temperature environment than the rice leaf-miner and the optimum zone of the activity is also broader than that of the rice leaf-miner.

3) The Diurnal Activity of the Corn-linear Leaf-miner

The result of the laboratory experiment concerning the temperature reaction of the activity of the fly are mentioned above. However, it may be very interesting and also important to compare the above result with the diurnal activity of the fly.

The fly is generally inactive during the night, resting on the upper or lower surface of the leaf or on the stem and it becomes active with the sunrise. The observations of the diurnal activity of the fly were tabulated in Table 3 (No. 1 & 2) and the diurnal change of the macro-climatic conditions are shown in Fig. 3.

Table 3. Diurnal activity of the Corn-linear Leaf-miner

No. 1: May 18th, 1953.

Time	Air Temperature (°C)	Sunshine	Observation
4.00 a.m.	9.0	darkness	None walk.
.40	9.5	twilight	One female fly walks slowly. Two female and three male flies move the hind legs and pass their legs across their wings.
.50	9.7	sunrise	One female and male flies walk.
5.30	12.0	slightly overcast	The fly can fly if I give an impetus to it. The larvae are feeding on the tissue of the mesophyl.
5.43	12.2	〃	One female fly begins flying and other flies walk.
6.00	13.0	soft-sunbeam	All flies migrate towards the sun light(the eastern upper part and upper part of eastern side) rest and move the hind legs.
7.00	14.5	slightly overcast	All flies are generally in the normal activity.
.30	17.3	sunbeam appeared from between the clouds	The same.
8.00	18.0	cloudy	One female and male rest.
.50	22.6	soft-sunbeam	All flies are walking and flying. A couplation is seen. One female fly rests in the shade.
9.00	25.8	shiny	All flies rest in the shade.
.45	27.0	〃	The same.
10.00	27.0	soft-sunbeam	One female walks and flies. Others are resting.
.37	26.5	shiny	One female is resting on the upper surface of the leaf. When the sun shins it migrates to the lower surface of the leaf and rests there.
11.35	25.2	soft-sunbeam	All flies are in normal activity.
12.00	24.0	shiny	One female oviposits in the tissue of the lower side of leaf.
13.40	23.5	cloudy	The same female oviposits again.
14.00	22.5	〃	All flies are walking and flying.
15.00	20.8	〃	The same.
16.00	23.4	〃	The same.
17.00	20.0	〃	The same.

18.00	18.9	cloudy	The same.
.30	16.7	sunset	The same.
19.06	17.0		One female fly rests.
.20	16.0	twilight	All flies rest.
20.00	11.0	darkness	The same.

No. 2: May 22nd, 1953.

Time	Air Temperature (°C)	Sunshine	Observation
5.00	15.8	cloudy	No active fly is seen.
.30	17.0	〃	One male begins to walk slowly and others are resting.
.55	17.2	〃	One female begins to walk slowly.
6.00	17.2	〃	Two more flies are walking.
7.00	18.3	〃	One female fly begins to fly.
8.00	18.9	〃	All flies are walking and flying.
9.00	19.2	〃	The same.
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19.00	17.0	rain	All flies are in normal walking.
.15	〃	〃	None walk.

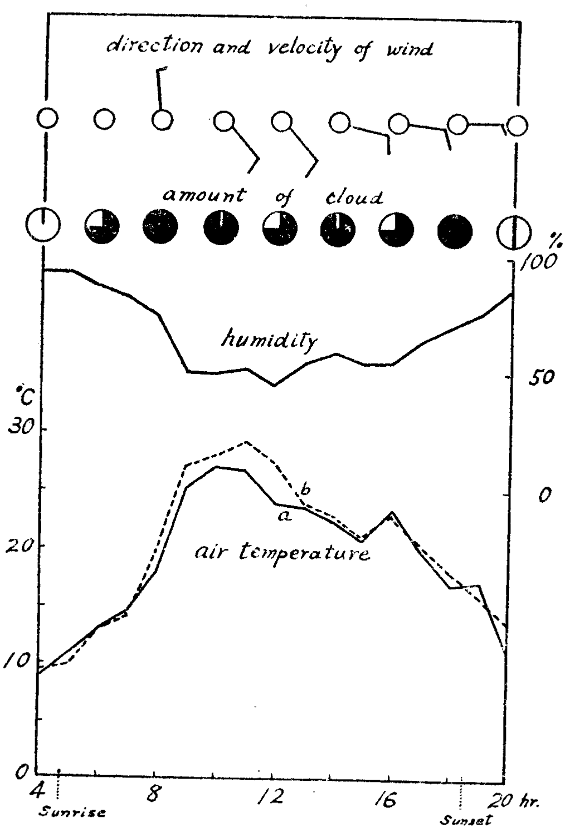

Fig. 3. The diurnal rhythm of the macro-climatic conditions.
a: upper zone of grass-growing; b: middle zone of plant.

1. The walking of the fly was observed at 4.40 a.m. on the 18th of May (fine day) and at 5.30 a.m. on 22nd of the same month (cloudy day). On these two days the air temperature was 9.5° and 17° C respectively. The process of the transformation from the resting to the active condition was very different on each day. In general, activity of insects begins more rapidly and earlier in the time in a fine than in a cloudy weather.

The air temperature at which walking began almost agrees with that of laboratory experiments on reaction of walking. This was because of similar environment in the laboratory for in the field in the early morning there being no solar radiation.

2. The flying of the fly begins at air temperature 12.2°C (5.43 a.m.) in the field. This is lower than the temperature 17°C at which the fly began flying in laboratory. This is because of the body temperature under field conditions rises more rapidly due to absorption of solar radiant energy than under laboratory condition. The same phenomenon was observed in the case of the rice leaf-miner (KATO, 1948). It is suggested from the above that the solar radiant acts as a heat energy which influences upon the activity of the fly.

3. When the air temperature rises above 26°C and the sun is shining, one of the flying flies becomes tumultuous while most of them rest in the shade to avoid the high temperature. The air temperature in this case is lower than that of the laboratory experiment. The reason for this is similar to that mentioned above.

4. The flies are often observed to flying even when it is drizzling in the field.

5. The influence of the wind-direction and wind-intensity on the activity of the fly was not proven.

6. As mentioned above, the diurnal rhythm of activity of the leaf-miner seems to depend mainly upon the diurnal change of the temperature factors.

4) **The Locomotive Velocity of the Corn-linear Leaf-miner**

It has been reported by many authors that the ARRHENIUS' Law is often adopted in activity of various insects. In this experiment, using this law I measured the velocity of locomotion in climbing behavior under a gradually rising temperature and this results are tabulated in Table 4 and shown in Fig. 4.

Table 4. Locomotive velocity of the fly under gradually rising temperature

Temperature (°C)	Velocity (cm/sec.)	Temperature	Velocity
10.0	0.4722	24.0	1.3514
12.0	0.5193	25.0	1.4167
14.0	0.6349	26.0	1.5385
15.0	0.6608	27.0	1.7692
16.0	0.6977	28.0	1.9511
17.0	0.7218	29.0	2.0417
18.0	0.7500	30.0	2.0426
19.0	0.8108	31.0	2.1743
20.0	0.8995	32.0	2.2340
21.0	1.0140	33.0	2.3864
22.0	1.1434	34.0	2.5063
23.0	1.2280	35.0	2.5658

The cure of the Fig. 4 is represented by the following ARRHENIUS's formula.

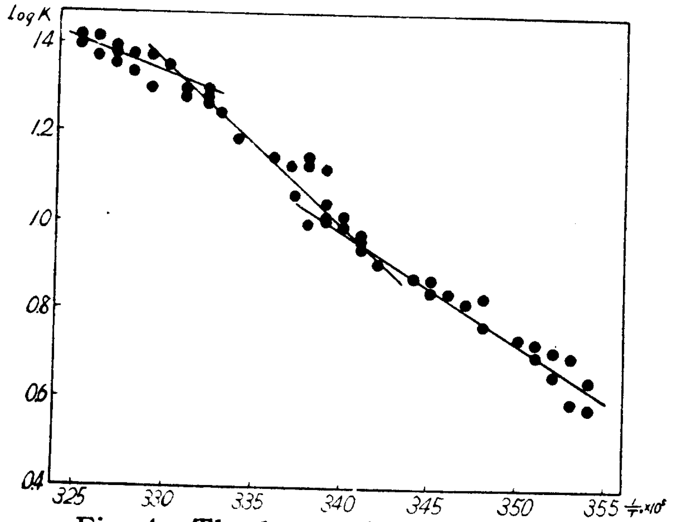

Fig. 4. The locomotive velocity of the Corn-linear Leaf-miner.

$$K_2=K_{1e}^{\frac{\mu}{2}(T_1-T_2)}$$

(K_1 and K_2 represent the velocity in the case of the absolute temperature T_1 and T_2 respectively; μ represents the temperature increment.)

The critical temperatures were 20.0° C and 29.03° C, and the temperature increments were as follows:

Below 20° C .... $\mu=11372$

20 - 29° C .... $\mu=14464$

above 29° C .... $\mu=7146$

The critical temperature 20° C somewhat agrees with the temperature 17.6° C at which the fly begins to fly. Likewise 29.03° C somewhat allies to the temperature 33.5° C at which the fly becomes nervous from heat. In the case of the Corn-blotch Leaf-miner, the critical temperatures (5.3° C and 29.6° C) of the movement of the mouth hook of the larva agree with the temperatures at which the larva begins to crawl and to become nervous (YAMASHITA, 1952).

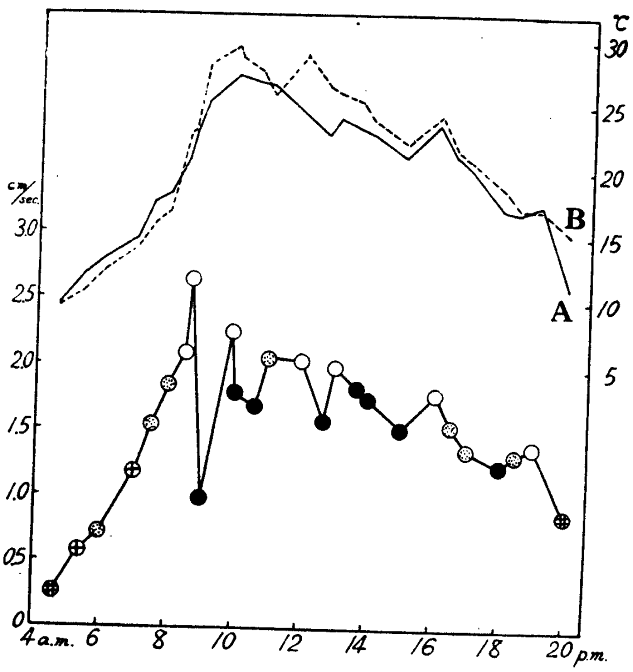

Fig. 5. The locomotive velocity of the fly measured under the field condition.

A: Air temperature; B: Soil surface temperature.

○ shiny; soft-sunbeam; ⊕ slightly overcast; twilight; ● cloudy.

5) The Locomotive Velocity under the Field Condition

The locomotive velocity measured under the field condition are shown in Fig. 5.

As distinctly shown in the figure, when the fly was active under solar radiation, climbing velocity diminished whenever a passing cloud obscures the sun. Conversely, when the fly was active in cloudy weather, velocity increased rapidly whenever the sun appeared suddenly. Consequently it was concluded that the presence and absence of the solar radiation exerts an important influence upon the locomotive velocity of the fly. Before 8.00 a.m., however, when there was a little solar radiation, climbing velocity increases with the increase of air temperature.

In addition, the comparison of locomotive velocity under field conditions with that in the laboratory experiment is important. The locomotive velocity under the various temperatures in the field is distinctly larger than that in the laboratory, though velocity in the field at twilight and just after sunrise is approximately similar to that in the laboratory. In this investigation, the solar radiation thermometer suggested by KATO (1938), was not used. However, in this case, it is also recognized that the locomotive velocity of the fly is influenced clearly not only by the environmental air temperature, but by the large amount of solar radiant energy absorbed.

Summary

The investigations were carried out to know the temperature limit of activity, the locomotive velocity and the diurnal activity of the fly of the corn-linear leaf-miner, *Phytomyza nigra* MEIGEN. The results may be summarized as follows:

1. The range of temperature zone of normal activity was 31.8−10.3° C≒22° C in female and 35.0−9.3° C≒26° C in male.

2. Comparing to the other leaf-miners, the range of temperature zone of normal activity of this fly is closely allied to the corn-blotch leaf-miner and it narrower than of the chrysanthemum leaf-miner and the ranunculus leaf-miner but broader than of the rice leaf-miner and soy-bean root-miner.

3. The diurnal rhythm of activity of the fly is affected mainly by the diurnal change of temperature so that it depends upon the temperature reaction. The lower limit of activity of the fly is about 10° C in the field.

4. In cloudy weather, the condition of rest gradually changes into of activity and the time beginning of activity is later than in fine weather.

5. The locomotive velocity, measured under gradually rising temperature, was calculated with ARRHENIUS' formula. The critical temperatures are at 20° C and 29.03° C, and these temperatures somewhat agree with the temperatures at which the fly begins to fly and becomes nervous, i.e. 17.6° C and 33.5° C respectively. The temperature increments are as follows:

Below 20°C .... $\mu=11372$

20°C - 29°C .... $\mu=14464$

above 29°C .... $\mu=7146$

6. The locomotive velocity under field conditions is very much intimately affected by the presence or absence of solar radiation.

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