Studies on the Seed-Corn Maggot.
II.

By

Chukichi Harukawa, Ryôiti Takato
and Saburô Kumashiro.

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Introduction.

In 1930 the writers published a paper on the seed-corn maggot, *Hylemyia cilicrura* RONDANI, as the first report[1]. The results obtained from further investigations of this insect, continued from then to the present time, are described here as the second report.

Many difficulties were encountered during the course of these investigations. For instance, although we have succeeded in rearing the adult females to maturity, it was almost impossible to induce the adults to copulate in a breeding cage. In fact, the writers have not yet succeeded in getting them to copulate under laboratory conditions. At the time the first report was in preparation, the writers had not been able to determine the length of the preoviposition period of the adult of this insect. From rearing of adults in the insectary, it was thought that the preoviposition period of this insect would be very long. Later, after trying various methods of rearing and various materials as food, the writers at last succeeded in bringing the adult flies to maturity and as a result found that the preoviposition period was not so long as they had at first supposed it to be.

On account of these difficulties, as well as many others which need not be enumerated here, the progress of the work has been slow and it has, in some instances, become necessary to modify slightly certain of the views which were set forth in the previous report.

I. Seasonal Occurrence of the Adult Insects.

Knowledge of the seasonal occurrence of the adult insects of the seed-corn maggot is important not only from the biological view-point, but also from the practical point of view. In the first report, the writers stated that the adult insects are found even in the winter, though the number is very small, and also that a small number of them may emerge even in January and February. The observations and experiments which were carried out since that time corroborated what has been stated above.

Under the climatic conditions which exist at Kurashiki, the egg and the larva grow even during the winter, but the pupa seems to cease development on very cold days or at least for several hours during a cold day. In other words, the temperature of the air often descends below the minimum temperature required for development of the pupa and the pupal period is often much prolonged on that account. That this phenomenon actually occurs will be shown in a later paragraph.

Experiments were carried out in the field in 1930 to 1931 in order to attain data on the seasonal occurrence of the adult insects. The field in which these experiments were carried out is sparsely planted with pear-trees between which soy-beans are planted in the summer while common beans are planted in the winter and spring. Since there is little precipitation at Kurashiki, the soil of the field dries in the summer and becomes hard.

The method of study was as follows: A glass fly-trap was used to capture the adult flies of the seed-corn maggot. Dried pupae of the silk-worm were used as the attrahent. The flies which were caught in the trap were taken out at certain intervals and the number was recorded. It has been considered that the results obtained show how the number of active adult insects varied in different seasons. The results of the experiments are presented in Table I.

(See Table I on next page.)

When the average number of flies captured per day, as shown in Table I, are plotted against the time of capturing, we obtain Figure 1.

Fig. 1.

Seasonal Variation in the Number of Adult insects.

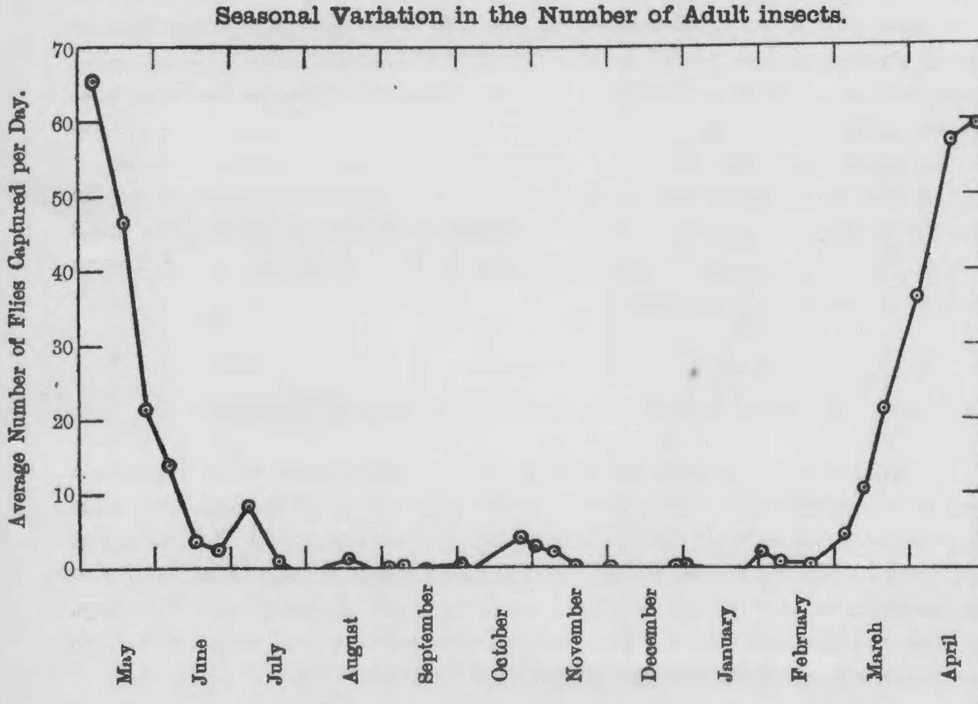


Table I.

Seasonal Occurrence of the Adults of the Seed-Corn Maggot.

Period in which Flies were Captured					Number of Flies Captured	Average Number of Flies Captured per Day
May	,6	—	May	10, 1930	258	64.5
〃	21	—	〃	24	140	46.6
〃	29	—	〃	31	43	21.5
June	6	—	June	9	42	14.0
〃	16	—	〃	19	11	3.6
〃	23	—	〃	28	14	2.8
July	5	—	July	11	51	8.5
〃	16	—	〃	19	2	0.6
〃	19	—	〃	22	0	0
〃	26	—	〃	30	0	0
Aug.	2	—	Aug.	5	1*	0.3
〃	5	—	〃	8	0	0
〃	15	—	〃	18	4	1.3
〃	22	—	〃	26	0	0
Sept.	1	—	Sept.	4	1	0.3
〃	8	—	〃	11	1	0.3
〃	15	—	〃	19	1	0.2
〃	26	—	〃	30	0	0
〃	30	—	Oct.	4	2	0.5
Oct.	4	—	〃	9	0	0
〃	23	—	〃	28	20	4.0
〃	28	—	Nov.	5	23	2.8
Nov.	5	—	〃	11	13	2.1
〃	11	—	〃	18	0	0
〃	24	—	〃	29	0	0
〃	29	—	Dec.	5	1	0.1
Dec.	13	—	〃	20	1	0.1
〃	20	—	〃	26	1	0.1
〃	26	—	Jan.	7, 1931	5	0.4
Jan.	7, 1931	—	〃	14	0	0
〃	14	—	〃	21	0	0
〃	26	—	〃	31	0	0
〃	31	—	Feb.	6	13	2.1
Feb.	6	—	〃	12	4	0.6
〃	18	—	〃	24	3	0.5
Mar.	3	—	Mar.	10	30	4.2
〃	10	—	〃	16	65	10.8
〃	16	—	〃	23	151	21.5
〃	30	—	April	6	255	36.4
April	13	—	〃	18	286	57.2
〃	18	—	〃	23	297	59.4

* This was captured in the botanical garden of the institute.

An examination of Table I shows the following facts: In 1930 to 1931, the flies of the seed-corn maggot were most abundant in March, April and May. The number of adults decreased markedly by the middle or the end of July. In August and September an extremely small number of flies were present, but the number increased considerably in October and November. The flies decreased in number again by the end of November and were very scarce in December and January. Thus, it is evident that there are two periods when the adults of the seed-corn maggot are abundant and also two periods when they are scarce. The periods of abundance and of scarcity occur alternately. In 1930 the number of flies occurring at the second period of abundance was rather small. The time at which the periods of abundance and of scarcity occur differs slightly in different years, but roughly speaking the first period of the maximum number of flies comes in April and the second maximum occurs in October. The first period of the minimum number of flies comes usually in the first ten days of August and the second period of scarcity occurs about the middle of January.

These results agree well with indication of the seasonal changes in the number of adult insects as was indirectly determined in 1928 to 1929 from the relative percentage of injury caused to soy-beans planted at different periods. A slight difference, however, occurred in the times of abundance and scarcity of the adults as determined from these two experiments.

It is noteworthy to find that even during the periods of scarcity a small number of flies were caught at intervals of several days, which fact indicates that active adults of the seed-corn maggot were not entirely absent even at those periods.

II. Seasonal Distribution of the Larva and Pupa.

The seasonal variation in the percentage of injured soy-beans was described in the first report according to the results of experiments made in 1928—1929. Similar experiments were also carried out in 1930—1931, but the method of experimentation was modified slightly in order to learn the seasonal fluctuation in the number of larvae and pupae.

A definite number of soy-beans were sown at each time in a definite length of shallow groove made in the field. When a certain number of days had elapsed from the time of sowing, the groove was carefully examined, a count being made of the number of injured soy-beans and of the number of seed-corn maggots and pupae found in the groove. This procedure was repeated regularly at certain intervals throughout an entire year.

The results of the observations are shown in Table II.

Table II.

Seasonal Changes in the Abundance of Larvae and Pupae of the Seed-Corn Maggot and in the Percentage of Injured Soy-Beans.

Dates of Planting	Total Number of Soy-beans Examined	Percent. Injured Soy-beans	Number of		Number of Insects per 100 Soy-beans
			Larvae	Pupae	
April 4, 1930	129	29.4	53	20	56.6
〃 28	149	55.7	324	0	217.4
May 13	119	11.7	19	45	53.7
〃 31	129	21.7	53	0	41.0
June 10	134	5.2	7	2	6.7
〃 19	125	21.6	99	1	80.0
〃 26	138	1.4	2	2	2.8
July 2	—	0	0	0	0
Aug. 14	—	0	0	0	0
Sept. 5	56	—	3	0	—
〃 13	119	1.6	0	2	1.6
〃 26	74	—	0	5	6.7
Oct. 14	87	63.2	99	6	120.6
〃 21	207	54.1	255	0	123.0
〃 29	105	58.0	159	0	151.4
Nov. 5	146	9.5	80	0	55.5
〃 14	81	35.6	103	0	127.1
〃 29	137	5.1	7	0	5.1
Dec. 6	144	0	0	0	0
〃 17	89	2.2	2	0	2.2
〃 31	107	0	0	0	0
Jan. 16, 1931	144	0	0	0	0
〃 29	145	2.7	4	0	2.7
Feb. 4	142	0	0	0	0
〃 21	151	7.9	21	0	13.9
March 6	148	14.8	35	0	23.6
〃 19	133	36.0	10	2	9.0

The results in Table II agree in general with what has been stated in the previous section. From examination of the records presented in the table, it is evident that during an entire year there are two periods when the seed-corn maggots are scarce. The larvae and pupae were very abundant in April and May and gradually decreased in number toward the beginning of June. About June 20th the number of larvae and pupae increased suddenly, but decreased again toward the end of that month and neither the larvae nor pupae were found in July and August. Early in September a small number of larvae were discovered. The number gradually increased in October reaching a second maximum about the end of that month. Abundant numbers were present throughout November and early December. A marked decrease occurred from the middle of December and almost no larvae or pupae were found in the first half of January of the next year. From the middle of February the numbers again gradually decreased. Thus, it is evident there are two periods, respectively, when the seed-corn maggots are most abundant and when they are most scarce.

Side by side with the observations just described, the percentage of injured soy-beans was also determined. The trend of the increase and decrease of this percentage was quite in harmony with the seasonal distribution of larvae and pupae as might be expected from the outset.

These findings agree in the main with the results which were described in connection with the seasonal occurrence of adults, but a closer examination reveals that there are some discrepancies between the two. In the first place, neither larvae nor pupae were found in July and August in the present experiment, whereas in the previous experiment a very small number of adult insects were captured in these months. The fact that no larvae were found in the field in July and August is probably due to the high temperature of the upper layer of the soil in these months. It is quite possible that larvae which may hatch out in these months are killed by the high temperature of the soil of the field. In regard to this point, we hope to make an experimental study in the future.

In the second place, the writers were not able to find any larva in the interval from the end of December to the end of January although a few adults were captured during that time as is indicated in the experiment which was described in the previous section. This discrepancy in the results may be explained in the following manner. Though a few adults may emerge in January, they would be active only on a very few warm days. Moreover, it takes a fairly long time for a female insect to reach maturity and to oviposit. Therefore, the number of adult insects which can lay eggs would be very small in the winter so that the larvae which hatch out in January or in February would also be extremely scarce. Thus it seems to be quite possible that no larvae would be observed in these cold months in experiments in which only a limited area of the field could be examined, even though adult flies were actually found to be present at the time.

III. Development and Growth of the Seed-Corn Maggot in Different Seasons.

Rearing of the seed-corn maggot was carried on in the insectary in 1928–1931 in order to study the seasonal history and the rate of development and growth in different seasons. The results obtained will be described in this section.

Method of rearing. Petri-dishes or small glass pots with covers were used as a container. A small quantity of soil from the field containing approximately 40 to 50 percent moisture was placed in the container and a number of eggs, for which the time of deposition was known, were placed upon the soil. A few soy-beans, which had been soaked in water beforehand and were about to sprout, were sown in the soil as food for the maggot. Since the containers had glass covers, the loss of moisture from the soil in the container must have been very little. However, water was added when it seemed necessary.

The results of rearing. The rearing records were classified into a few groups as this was found to help in obtaining a correct understanding of the significance of the results. Thus, for the egg and the larva, 2 seasons were distinguished, namely, the *spring-summer* season and the *autumn-winter* season. The former included the period from the end of February to the first ten days of July and the latter, the interval from October to the end of December or sometimes to the end of February. For the pupa another season was distinguished in addition to the 2 seasons mentioned above, namely, the *winter-spring* season. This included the period from the end of December to the end of March or sometimes to the end of April. The data on the length of the three stages, the egg, the larval and the pupal, were classified according to the three seasons distinguished above and the number of days required to complete a stage, as well as the mean air temperature in the insectary for the period in which each individual developed, was calculated. When the mean temperature under which a number of individuals developed differed by only 0.1 to 0.2°C., the number of days required by these individuals to complete a stage were averaged together. The use of this method in averaging seemed to be appropriate because individual differences in their responses to temperature, as well as other unknown conditions in rearing, affected the duration of the stage much more markedly than the small differences in the temperature under which different individuals developed. The results of rearing are presented in Tables III, IV, V and VII.

(See Table III on next page.)

i) Egg period.

According to Table III, the egg period in the *spring-summer* season was 2 days in the early part of June when the mean air temperature was about 20°C. In the *autumn-winter* season it was 2 days when the mean air temperature was 19°C. The development of the egg did not seem to proceed faster even if the temperature of the air rose 2 or 3°C. higher than 19 or 20°C. The egg period became gradually longer with the fall of temperature. For instance, the egg period in the first ten days in April was about 5.5 days when the mean temperature was about 12°C.; in the first half of March it was about 9 days when the mean temperature was about 9°C.; and in February the egg period was about 17 days at a mean temperature of about 6°C.

The relation of the mean temperature to the length of the egg period is shown in Figure 2. The curves in this figure show clearly that the egg period decreases fairly regularly with the rise and fall of temperature.

Table III.

Egg Period.

(1) *Spring-Summer* Season.

Period	Average Egg Period in Days	Mean Temperature for the Period in °C.
Feb. 21, 1931 — March 7	15.0	6.6
March 6 〃 — 〃 14	9.0	9.1
Feb. 20, 1930 — Feb. 25	6.0	11.2
March 29, 1928 — April 5	5.6	11.7—11.9
〃 30 〃 — 〃 7	5.4	12.0—12.1
April 6 〃 — 〃 9 } March 30, 1929 — April 3 }	5.1	12.3—12.4
May 14 〃 — May 16	3.0	17.5
〃 16, 1928 — 〃 18	3.0	18.2
April 18, 1930 — April 20	3.0	18.6
June 4 〃 — Jnne 6	2.0	20.5
〃 5, 1929 — 〃 6	2.0	22.2
〃 18, 1930 — 〃 19	2.0	23.1
(2) *Autumn-Winter* Season.		
Feb. 4, 1931 — Feb. 22	17.6	6.2
Nov. 30, 1929 — Dec. 6	7.0	11.4
〃 4 〃 — Nov. 6	3.0	13.9
〃 1 〃 — 〃 3	3.0	14.7
Oct. 9, 1928 — Oct. 11	3.0	17.5
〃 7 〃 — 〃 8	2.0	19.3
〃 25 〃 — 〃 26	2.0	19.5

Fig. 2.

Mean Temperature and Egg Period.

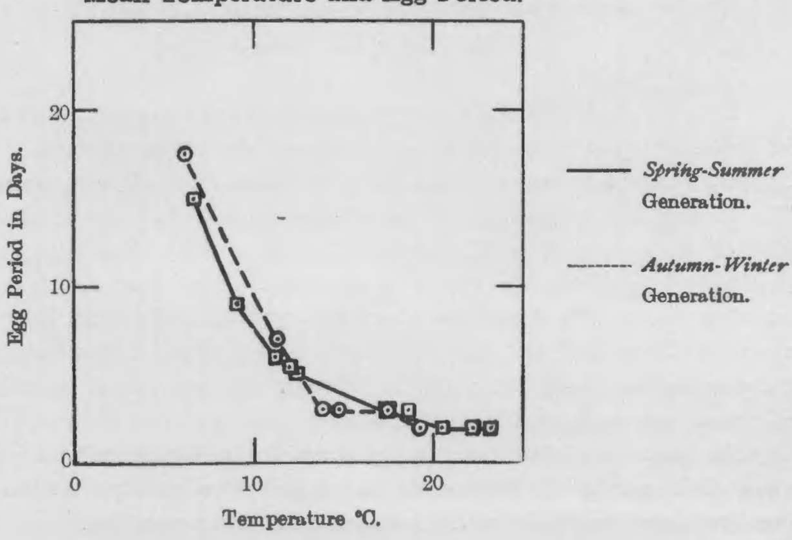


Table IV.

Larval Period.

(1) *Spring-Summer* Season.

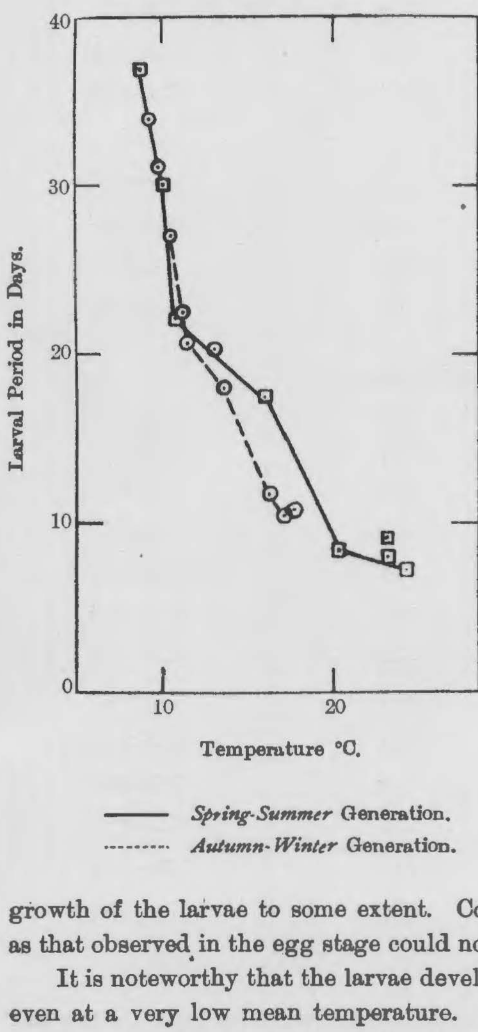
Period	Mean Larval Period in Days	Mean Temperature for the Period in °C.
Feb. 21, 1931 — March 29	37	8.9
〃 26, 1930 — 〃 27	30	10.0
〃 26 〃 — April 3	33.7	10.2—10.4
March 15, 1931 — 〃 5	22.0	10.9
April 21, 1930 — May 9	17.5	16.0—16.1
May 19, 1928 — 〃 27	8.4	20.4—20.5
〃 19 〃 — 〃 28	10.0	20.7
June 6, 1930 — June 17	10.6	22.8—22.9
〃 7 〃 — 〃 16	9.2	23.0—23.2
〃 7 〃 — 〃 14	8.0	23.4
〃 20 〃 — 〃 28	7.2	24.4—24.5
(2) *Autumn-Winter* Season.		
Dec. 7, 1929 — Jan. 9, 1930	34.0	9.3
〃 7 〃 — 〃 6 〃	31.0	9.8
〃 7 〃 — 〃 2 〃	27.0	10.5
〃 7 〃 — Dec. 29	22.4	11.1—11.3
〃 7 〃 — 〃 27	20.5	11.4—11.6
Nov. 4 〃 — Nov. 27	23.2	12.6—12.7
〃 4 〃 — 〃 24	20.3	13.0—13.2
〃 4 〃 — 〃 21	18.0	13.6
Oct. 27, 1928 — Nov. 7	11.7	16.3—16.4
〃 12 〃 — Oct. 23	10.4	17.1—17.2
〃 9 〃 — 〃 20	10.5	17.4—17.5
〃 9 〃 — 〃 19	10.8	17.6—17.8

ii) Larval Period.

According to Table IV, (1), the larval development was most rapid in the last third of June. The larval period was about 7 days when the mean temperature was 24.5°C. In the last third of May it was about 8 days when the mean temperature was about 20.5°C., while it was about 22 days in the interval from the last half of March to the first third of April when the mean temperature was 11°C. In the period from the last ten days in February to the end of March, when the mean temperature was approximately 8 to 9°C., the larval period was about 37 days.

The relation between the larval period and the mean temperature in the *autumn-winter* season was on the whole similar to that in the *spring-summer* season. For instance, the larval period was about 34 days when the mean temperature was about 9°C., and about 20 days at a mean temperature of 12—13°C. The larval period in the middle part of October was about 10.5 days when the mean temperature was about 17°C.

Fig. 3.
Mean Temperature and Larval Period.



The relation of the mean temperature to the duration of the larval period is shown graphically in Fig. 3.

When there were two or more mean values of the larval period which differed slightly although the larvae were reared under approximately the same mean temperatures, the shorter larval period was adopted for drawing the curves shown in Fig. 3. This procedure was followed because it was considered that some factors other than temperature must have affected the larval growth in those experiments in which the longer larval period was observed.

The relative humidity must have influenced the larval growth very little since the larvae were in the moist soil in the glass containers. However, it can not be denied that a combination of certain factors, of which the relative humidity must have been one component, has affected the growth of the larvae to some extent. Consequently, a very uniform result such as that observed in the egg stage could not be obtained in the case of the larvae.

It is noteworthy that the larvae developed with a fairly rapid rate of growth even at a very low mean temperature. Thus, in December or in February the larvae continued to grow and completed the larval stage in 34 to 37 days at a mean temperature of about 9°C., which may be lower than the threshold of growth for many other insects.

iii) Pupal Period.

The number of individuals which passed through the pupal stage successfully was not large so that the data relating to the pupal stage were not so accurate as those relating to the egg and to the larva. The results are shown in Table V.

Table V.

Pupal Period.

(1) *Winter-Spring* Season.

Period	Mean Pupal Period in Days	Mean Temperature for the Period in °C.
Dec. 7, 1929 — March 29, 1930	*89—92	*7.6—7.9
Jan. 7, 1931 — April 14	75—93	7.6—8.4
〃 1, 1930 — 〃 4	83—90	7.8—8.3
(2) *Spring-Summer* Season.		
March 30, 1931 — May 3	29.0	13.5—13.6
〃 30, 1930 — April 24	26.0	13.9
〃 28, 〃 — 〃 24	26.7	14.0—14.2
April 1, 〃 — 〃 24	24.0	14.3
〃 2, 〃 — 〃 24	22.6	14.5—14.6
〃 3, 〃 — 〃 25	22.5	14.8—15.0
May 6, 〃 — May 22	15.7	19.5—19.6
〃 8, 〃 — 〃 26	15.3	19.8—19.9
〃 9, 〃 — 〃 24	14.8	20.0—20.1
〃 9, 〃 — 〃 23	13.7	20.2—20.3
〃 27, 1928 — June 9	13.6	22.0
June 15, 1930 — 〃 27	11.6	23.6—23.8
〃 17, 〃 — 〃 27	10.6	24.0—24.1
〃 26, 〃 — July 6	9.8	26.0—26.1
〃 27, 〃 — 〃 6	9.8	26.3—26.4
〃 28, 〃 — 〃 7	9.2	26.6—26.7
(3) *Autumn-Winter* Season.		
Nov. 27, 1929 — Jan. 23, 1930	58	8.9
〃 24, 〃 — 〃 23, 〃	52.7	9.3—9.4
〃 22, 〃 — 〃 11, 〃	51.0	9.6
〃 7, 1928 — Dec. 16	37.6	11.6—11.7
〃 7, 〃 — 〃 7	31.0	12.5
Oct. 20, 〃 — Nov. 7	16.4	16.7—16.8
〃 9, 〃 — 〃 8	16.5	16.9—17.0

* These figures show the ranges of the mean values.

The results obtained in the *spring-summer* season will be examined first. When pupation occurred in the last ten days of March the pupal period was 29 days at a mean temperature of about 13.5°C. The pupal period gradually decreased with the rise of the mean temperature. For instance, it was approximately 15 days in the first third of May when the mean temperature was about 19.8°C, and about 9 days in the last third of June to the first ten days in July when the mean temperature was about 26.6°C.

According to the observations made in the *autumn-winter* season, the pupal period was approximately 16 days in the interval from the middle of October to the first third of November when the mean temperature was about 16.7°C., while it was approximately 37 days in the first half of November to the middle of December when the mean temperature was about 11.6°C. Thus, the development of the pupae proceeded without any pause entering in until about the middle of November, though the pupal period became longer in proportion to the fall of the mean air temperature. After the 20th of November, however, the development of the pupae sometimes seemed to enter a temporary standstill. This cessation of development may have been a state of dormancy in some cases, while in the other cases it may have been simply a temporary standstill of development owing to the fall of the air temperature below the threshold of the pupal development. For instance, in a certain experiment in the *autumn-winter* season, the pupal period lasted for approximately 53 days from November 24th to January 23rd of the following year. In this case it does not seem that the development of the pupa proceeded without being interrupted by a standstill. The mean air temperature for this period was found to be about 9.4°C., but this temperature can not be considered the actual mean for the period during which the pupae were actually developing. The actual mean temperature must have been higher than 9.4°C.

In the *winter-spring* season the emergence of adult insects occurred from the end of March to the middle of April in the cases where the pupation occurred at the end of December or the beginning of January. [See Table V, (1)]. The apparent pupal periods in these instances ranged from 75 to 93 days. No doubt these pupae must have entered a dormant state of varying length of time and the development was resumed after the breaking-up of the dormancy. Therefore, the mean temperatures during these periods do not represent the actual mean temperatures which were effective for the development of the pupae.

The reason for considering that these pupae entered into a state of dormancy in the instances mentioned above will be stated below. In 1929 a number of larvae which hatched from the eggs laid on October 28th were reared in the insectary. The time of pupation of these larvae was not determined, but there was no doubt, judging from the results of the other rearing experiments, that pupation had occurred about the 20th of November. The emergence of adults from these pupae occurred as shown in Table VI.

Table VI.

Record of the Emergence of Adult Insects in the *Winter-Spring* Season.

Dates of the Emergence of the Adults	Number of Adults Emerged	*Pupal Period in Days	Remarks
December 26, 1929	1	36	Mean temperature in December ....10.8°C.
〃 30, 〃	1	40	
January 8, 1931	8	48	Mean temperature in January............ 5.8°C.
〃 23, 〃	11	63	
〃 29, 〃	1	69	
〃 30, 〃	1	70	
February 18, 〃	1	89	Mean temperature in February .... 7.2°C.
〃 23, 〃	1	94	
〃 25, 〃	2	96	
〃 27, 〃	4	98	
March 1, 〃	1	100	
〃 5, 〃	1	104	
〃 8, 〃	1	107	

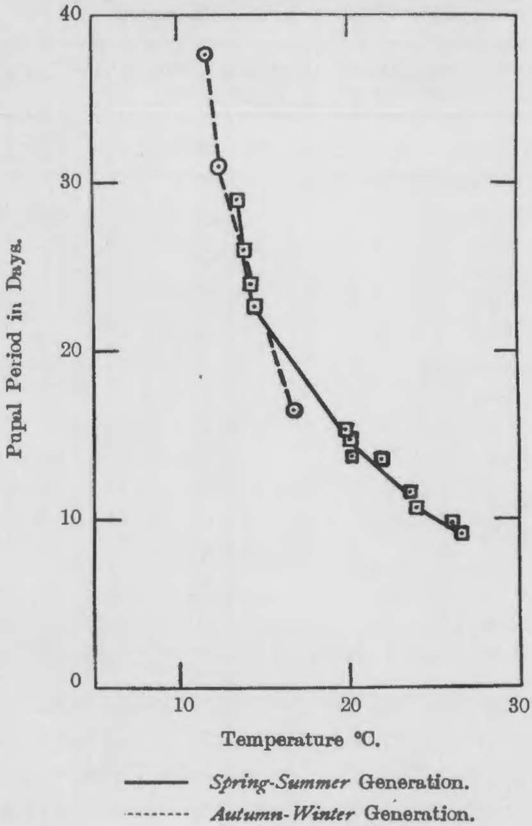
* It is assumed that the pupation took place on November 20th, 1929.

As is shown in the last column of Table VI, the mean temperature of the insectary in December, 1929 was 10.8°C. which was high enough for the development of the pupae. Therefore, in the cases where the adults emerged on and before January 8th the development of the pupae must have proceeded continuously although it might have been arrested for a short time on a very cold day. However, in the instances where emergence occurred after January 8th, the pupal periods were very long and the ranges of the pupal periods were extremely wide, being from 63 to 107 days. There seems to have been no other factors which might have arrested the emergence of the adults from the pupae.

It is noteworthy that the mean air temperature in the insectary was very low, being 5.8°C. in January and 7.2°C. in February, and also that the adult insects appeared at intervals from January to February in spite of the low mean temperature. When these facts are taken into consideration it seems justifiable to conclude that the pupae entered a dormant period of varying length owing to some unknown cause or causes and that the time of passing out of the dormancy differed in different individuals.

For the reasons stated above, the results of rearing experiments in which the mean temperature was 11°C. or higher were made use of for drawing the curves which show the relation of temperature to the duration of the pupal period. In addition, the data on the pupal periods were selected with the same precaution as was taken when constructing the similar curves for the larval development. The curves thus obtained are shown in Figure 4.

Fig. 4.
Mean Temperature and Pupal Period.



iv) Time required for completing the transformation.

The words "*time required for completing the transformation*" are used here to denote the duration of time from deposition of the egg to emergence of the adult insect. The preoviposition period is not included in this period. The data on the time required to complete the transformation are classified into the following three groups: (1) the data on the *spring generation*, (2) those on the *autumn generation*, (3) those on the *winter generation*.

Since the pupal period is included in the time required for completing the transformation, it must be borne in mind that both the period in which development is arrested temporarily and the dormant period of varying length are included in this time in cases where the pupal periods fall in the interval from the end of December to the first half of April. In such cases, the apparent duration of time required for completing the transformation ranged from 118 to 151 days. The mean temperature that existed during the time required for transformation in such instances was not calculated because the values so obtained would not represent the actual mean of the temperatures effective for development.

The results of observations on the time required for completing the transformation are shown in Table VII.

Table VII.

Time from the Deposition of Eggs to the Emergence of Adult Insects.

(1) *Spring Generation.*

Period	Mean Duration of Time in Days	Mean Temperature for the Period in °C.
Feb. 4, 1931 — April 30	85.3	9.7—9.8
〃 21, 〃 — 〃 30	68.0	10.5—10.7
〃 21, 〃 — May 3	71.0	10.8—10.9
〃 20, 1930 — April 25 March 6, 1931 — May 3	64.0	11.9—12.0
〃 29, 1929 — 〃 17	46.5	15.7—15.9
April 6, 1928 — 〃 18 March 30, 1929 — 〃 21	43.0	16.0—16.2
April 8, 1930 — 〃 19	41.0	16.7—16.9
〃 8, 〃 — 〃 20	43.0	17.0
〃 18, 〃 — 〃 26	36.1	17.9
May 14, 1929 — June 13	30.0	20.4—20.6
〃 16, 1928 — 〃 9	24.2	20.8—21.0
〃 16, 〃 — 〃 12	27.3	21.4—21.5
June 5, 1929 — 〃 30	24.2	22.9—23.0
〃 4, 1930 — 〃 26	22.8	23.1—23.2
〃 4, 〃 — 〃 27	24.0	23.3—23.4
〃 18, 〃 — July 7	18.9	25.1—25.3

(2) *Autumn Generation.*

Period	Mean Duration of Time in Days	Mean Temperature for the Period in °C.
Nov. 4, 1929 — Jan. 24, 1930	82.0	9.9
〃 4, 〃 — 〃 22, 〃	80.0	10.1—10.2
〃 1, 〃 — 〃 19, 〃	73.6	10.3—10.4
〃 1, 〃 — 〃 14, 〃	73.5	10.6—10.8
Oct. 25, 1928 — Dec. 16	51.6	12.9—13.1
〃 25, 〃 — 〃 7	44.0	13.7
〃 9, 〃 — Nov. 7 〃 10, 1929 — 〃 10	30.2	16.9—17.1
〃 7, 1928 — 〃 8	30.0	17.2—17.3

(3) *Winter Generation.*

Period	Ranges of the Mean Numbers of Days
November 30, 1929 — April 6, 1930	118—128
〃 10, 1930 — 〃 9, 1931	132—151
〃 22, 〃 — March 17, 〃	128—147
〃 29, 〃 — April 12, 〃	125—135

The data on the *autumn generation* will be examined first. A number of individuals that developed from the eggs laid at the beginning of November, 1929, emerged as adults in approximately 74 to 82 days. The development of these individuals seemed to have been arrested for a varying length of time. The mean temperatures that existed during the life-cycle of these individuals were approximately 10.1 to 10.8°C., but these do not represent the actual mean of the effective temperatures during the periods in which the development actually took place. The actual mean temperatures must have been a little higher than these apparent mean temperatures. [Table VII, (2)].

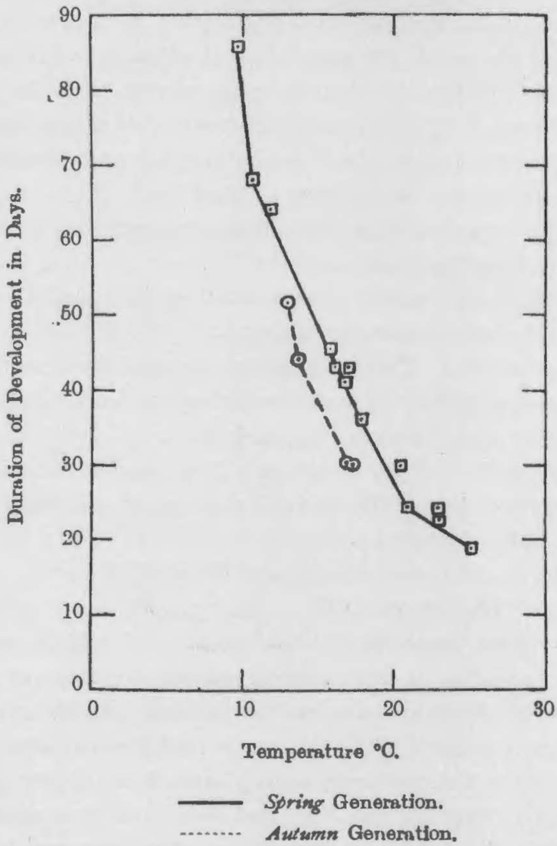
Next, the results obtained with the *spring generation* will be examined. It is evident from the records in Table III that the egg of the seed-corn maggot develops under a very low temperature. For example, the eggs laid on February 4th, 1931, required 17.6 days at a mean temperature of 6.2°C. The development of the eggs seemed to have progressed without any pause during this period. Judging from this observation, it may be assumed that the individuals of the *spring generation* which are shown at the beginning of Table VII must have developed without pause from the time the eggs were deposited until the adults emerged. The individuals that developed from the eggs laid on February 4th, 1931, completed the transformation in approximately 85 days at a mean temperature of 9.7 to 9.8°C. and those from the eggs of February 21st, 1931, in from 68 to 71 days at a mean temperature of 10.5 to 10.9°C. These individuals seemed to have completed the transformation without being interrupted in their development. [Table VII, (1)]. The number of days required to complete the transformation gradually decreased with the rise of temperature. Those individuals that developed from the eggs which were laid in the first third of April completed the life-cycle in about 42 days at a mean temperature of approximately 17°C., those from the eggs laid in the first ten days in June, in 23 to 24 days at a mean temperature of approximately 23°C., and those from the eggs laid in the middle of June, in about 19 days at a mean temperature of about 25°C. In the *autumn generation*, the number of days required to reach the adult stage was about 30 days at a mean temperature of about 17.2°C. for the individuals from the eggs which were laid on October 7th, 1928 and it was about 52 days at a mean temperature of 13°C. for the individuals from the eggs which were laid on October 25th, 1928.

In short, the time which elapses from deposition of the egg until the appearance of the adult insect of the seed-corn maggot varies from 18 days to approximately 85 days according to the mean air temperature during the period of development. For the eggs which are laid near the end of autumn this duration is from 140 to 150 days, but this does not represent the actual duration which is required for the development and growth. It must be borne in mind that a dormant period of a variable number of days is included in the pupal period in the last case.

Taking these facts into consideration, Figure 5 was drawn in order to show the relation of the mean temperature to the duration of time required for completing the transformation.

Fig. 5.

Mean Temperature and Time from Oviposition to Emergence of Adult Insect.



According to the curves in Figure 5 it is clearly seen that the duration of the developmental period decreases markedly as the mean air temperature rises.

IV. Behaviour of the Seed-Corn Maggot during the Summer and Winter.

In the previous report, the writers stated that neither the flies nor the maggots were found in the field in the hot summer months[1), 2)], and also that all the puparia which were experimentally buried in the soil at the beginning of July emerged as adult insects shortly afterwards.

It is true that the adult flies of the seed-corn maggot are very scarce in a very dry field in the summer, but the experiments which were carried on in 1930—1931 showed that a very small number could be found there at times even in July, August and September. The results of the experiments which were carried out in these two years in order to study the behaviour of the flies in the summer will be described in the following paragraph.

Cotton-seed meal or dried pupae of the silk-worms, both of which were found to be favorite foods of the adult fly, were used as attrahents. A small quantity of these materials was placed in shallow glass vessels and the vessels were covered with glass fly-traps. These were distributed in the following four places.

(1) *Field, I.* The soil of this field was rather dry and became hard when there was no rain for a week or two. Pear-trees of about 5 to 7 feet in height were sparsely planted in the field and between these trees soy-beans were planted during the summer.

(2) *Field, II.* This was located near a small stream and the soil always contained a fairly large amount of moisture.

(3) *A small peach orchard.* This orchard was located in a sunny place. It was well drained and the soil was dry and quite hard. The fly-trap was placed in a shady place between the peach-trees.

(4) *The botanical garden* of the institute. This garden contained a dense growth of many tall trees. The ground was shady and the soil contained a moderate amount of moisture.

The results of the experiments are shown in Table VIII.

(See Table VIII on next page.)

In addition to those experiments the results of which are shown in Table VIII, similar experiments were carried out in the summer of 1931 and essentially the same results were obtained as in the summer of 1930. As is evident from the records in Table VIII, the number of flies captured varied with the different locations in which the traps were placed, but a fairly large number of flies were captured in the first two-thirds of July and the number decreased markedly after the 20th of July. A small number of flies were caught at intervals at each of the four locations during July, August and September. In 1931, 12 female flies were caught in the interval from the 15th to the 21st of September and after that time flies were caught successively in large numbers, whereas in 1930 the number of flies caught was strikingly less than in 1931. The cause of this difference in the number of the flies captured in September in these two years is not known at the present time.

It may be concluded from the results of these experiments that the adults of the seed-corn maggot are to be found, though in a small number, even in the hottest part of summer. It is noteworthy that the flies were not caught continually during July, August and September, but that only small numbers of flies were captured at intervals of some 10 or 15 days. Another noteworthy fact is that all the flies which were caught were females. In this respect, the result obtained in 1931 was quite in agreement with that obtained in 1930. These findings seem to indicate that the seed-corn maggot continues its life-cycle even in the hottest part of the summer at a place where the conditions are suitable to its life.

Table VIII.
Trapping Experiment in Summer.

Location	Attrahent used	Period in which Flies were Captured	Number of Flies Captured		
			♀	♂	Total
Field, I	Silk-worm pupae	July 1 — 5, 1930	2	1	3
〃	〃	〃 5 — 11	37	14	51
〃	〃	〃 12 — 19	1	1	2
〃	〃	〃 19 — 31	0	0	0
〃	〃	Aug. 1 — 12	0	0	0
〃	〃	〃 12 — 15	5	0	5
〃	〃	〃 15 — 18	4	0	4
〃	〃	〃 18 — 22	1	0	1
〃	〃	〃 22 — Sept. 1	0	0	0
〃	〃	Sept. 1 — 26	0	0	0
〃	〃	〃 26 — 30	1	0	1
Peach orchard	〃	July 22 — Aug. 12, 1930	0	0	0
〃	〃	Aug. 12 — 15	1	0	1
〃	〃	〃 15 — 31	0	0	0
〃	〃	Sept. 1 — 4	1	0	1
〃	〃	〃 4 — 8	0	0	0
〃	〃	〃 8 — 11	1	0	1
〃	〃	〃 11 — 15	0	0	0
〃	〃	〃 15 — 19	1	0	1
Botanic garden	Cotton-seed meal	July 5 — 11, 1930	2	0	2
〃	〃	〃 11 — 19	0	0	0
〃	Silk-worm pupae	〃 20 — Aug. 1	0	0	0
〃	〃	Aug. 2 — 5	1	0	1
〃	〃	〃 6 — 31	0	0	0
〃	〃	Sept. 1 — 7	0	0	0
〃	〃	〃 8 — 11	1	0	1
Field, II	〃	Aug. 7 — 14, 1930	0	0	0
〃	〃	〃 15 — 18	1	0	1
〃	〃	〃 18 — 31	0	0	0

The activity of the seed-corn maggot is at its height usually following a rain under the weather conditions prevailing at Kurashiki. Since there is very little rainfall in the summer at this locality, the temperature of the upper layer of the soil in the field rises very high and the soil becomes very dry. These conditions are apparently unsuitable to the life of the seed-corn maggot; consequently no larvae are found in a dry field in the summer.

REKACH reported that only pupae were present in the field in July and August according to observations made in Transcaucasia[5]. The result obtained from the observations made by the present writers is somewhat different from that obtained by REKACH, but it seems probable that at least a part of the larvae or pupae which are found in puparia about the end of July may pass the summer in a dormant state, although the writers have not yet succeeded in ascertaining that this actually happens. Further study in respect to this point will be worth while.

Behaviour of the seed-corn maggot in winter. In regard to the overwintering of the seed-corn maggot, the writers have stated that this insect passes the winter in either of three stages; the adult, the larval or the pupal stage. Further observations showed that the number of adults which appeared in January was usually very small, but it increased considerably after the middle of February. It was found that a considerable number of the flies which appeared from the middle of February to the 10th of March must have passed the winter within the puparia, their development being suspended temporarily during the cold season. Therefore, the number of individuals which pass the winter within puparia seems to be considerably greater than the writers had suspected when the first report was prepared.

That the seed-corn maggot may overwinter in the adult stage is quite conceivable judging from the result of the following experiment which was conducted in the winter of 1928—1929. A number of adult insects which emerged on December 4th, 1928, were placed in a breeding cage. Cotton-seed meal and water were given to them as food and the cage was kept in an open-air insectary. This open-air insectary is a net house with glass roof, the four sides being fitted with wire screen. The results obtained from observations on the longevity of the adult insects are shown in Table IX.

(See Table IX on next page.)

The temperature of the air in the open-air insectary was not exactly the same as the temperature outside. In most cases the minimum temperature in the insectary was slightly higher than the minimum temperature outside, but the mean temperature in the insectary was almost the same as the outside mean. Under these conditions, in the open-air insectary approximately one-half of the flies were alive for more than 100 days. Even during the cold season they were active on warm days and fed on the cotton-seed meal, but they hid themselves between soil clods on cold days and remained motionless. In the field the flies are certainly exposed to more severe weather conditions than in the experiment here described, but there is no doubt that the winter is passed in the adult stage judging from the experiment as well as from the field observations.

Table IX.

Longevity of Adults in Winter.

Examinations made on			Number of Living Adults	Approximate Longevity in Days	Remarks
December	31,	1928	11	—	
January	12,	1929	11	40	
〃	17,	〃	10		One died between January 12th and 16th.
〃	24,	〃	10	52	
〃	26,	〃	9		One died between January 24th and 26th.
March	12,	〃	9	99	
〃	14,	〃	7	101	Two died before March 14th.
〃	19,	〃	6	106	One died before March 19th.
〃	20,	〃	5	107	Living flies were killed by accident.

V. Summary.

1) The seasonal variation in the number of the adult insects of the seed-corn maggot was studied by using attrahents in traps for capturing the adults. According to the results obtained from this study, the adult flies of the seed-corn maggot were most abundant in March, April and May and were very scarce in July, August and September. The second period during which flies were present in most abundant numbers came in October and November, but during this period the flies were usually markedly fewer in number than at the first period of greatest abundance. Thereafter, the number of adult insects again decreased and the second period of scarcity occurred in December and January. These results agree fairly well with the seasonal distribution of the seed-corn maggot which was determined by a different method and reported in the first report.

2) Soy-beans were planted in small plots of a definite area and a count was made of the number of larvae and pupae found in the soy-beans and in the soil. The seasonal distribution of the seed-corn maggot, which was determined by this method, agreed in the main with the results which have been described in 1). The only variation between the results obtained by these two different methods was that no larvae were found in August, December and January in the present experiment.

3) The seed-corn maggot was reared in the rearing room, the length of each stage was determined and the relation of the mean air temperature in the insectary to the duration of each stage was worked out. According to the results obtained from this study, the egg and the larva of this insect continue to

develop even in the winter under the climatic conditions prevailing at Kurashiki, but the pupa ceases development temporarily in January and February and a certain portion of the pupae enter a short period of dormancy during the winter.

The number of days from the time of oviposition to the emergence of the adult insect varied markedly according to the season. When eggs were laid at the beginning of February, the duration of this period was approximately 85 days and the mean temperature during this time was about 9.7°C. The individuals that developed from eggs which were laid in the middle of July required from 18 to 19 days to attain the adult stage and the mean temperature for the period was about 25°C. When eggs were laid at the end of November or the beginning of December, the number of days required to reach the adult stage varied markedly in different individuals, but it was roughly 130 days in most cases. In this last case the development ceased in the pupal stage for a varying period of time as has already been stated.

4) The larvae of the seed-corn maggot were not usually found in a dry field in the summer, but small numbers of this insect seemed to live and produce summer broods in a place where the soil moisture as well as other conditions were favourable for their life. REKACH holds the opinion that the seed-corn maggot passes the summer in the pupal stage, but the writers have not been able to show that the estivation occurs in this manner. The winter is passed in any of the four stages; the egg, the larval, the pupal and the adult stage. The egg and the larva continue to develop even in the winter. The adult insects pass the winter by hiding themselves in crevices in the soil or in other protected places. Though they are scarce in the winter, they may be seen searching for food in the field on a calm, warm day.

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