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EXPERIMENTAL STUDIES REGARDING THE INFLUENCE OF TEMPERATURE AND RELATIVE HUMIDITY ON THE OVIPOSITION OF THE RICE WEEVIL (*CALANDRA ORYZAE* L.)

(米象產卵受溫濕度影響之實驗)

Tsai Pang-hwa, Chang Yen-nien
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EXPERIMENTAL STUDIES REGARDING THE INFLUENCE OF TEMPERATURE AND RELATIVE HUMIDITY ON THE OVIPOSITION OF THE RICE WEEVIL (*CALANDRA ORYZAE* L.)

Tsai Pang-Hwa and Chang Yen-Nien*

Contents

(with five figures and one table)

I. Introduction

The rice weevil (*Calandra oryzae* L.) is widely distributed, being found in the temperate, sub-tropical, and tropical zones; but it thrives best in the last two named. In China the authors have found it as far north as Kalgan (41 N.) and Sui-yuan (41°N.) and as far south as Canton (23°N.). The morphological characters closely resemble those of the granary weevil (*Calandra granaria L.*) although the rice weevil has hind wings with four marks on the elytra. It is found farther south than the granary weevil, too.

In spite of their wide distribution, the presence of the weevils to a serious extent is very irregular and varies with the year, season, and locality as well as with the storage buildings. From the results of this experiment, we can say that a very high humidity (90-100%) and a high temperature (24-29°C.) are the most effective factors in causing an outbreak of the rice weevil. However, oviposition is limited to a temperature not higher than 35°C., nor lower than 10°C., and to a relative humidity not less than 60%.

II. Material and Methods Used

The weevils used as experimental material were taken from wheat stored

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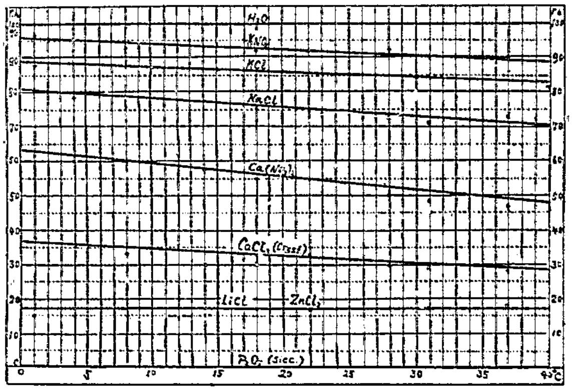
*The authors desire to express their appreciation to Misses W. S. Yang and C. Y. Tong for their technical assistance during these studies.

at the experiment station of the College of Agriculture, National Central University, Nanking. Since all the experimental material was obtained from the same place, we can suppose that the weevils were subject to the same environmental conditions during preceding generations.

For the experiments we first selected weevils of the same color and size and then divided them according to sex, putting one pair into each small bamboo pipe for rearing. The rearing pipe used is about 3 cm. in length and .7 cm. in diameter with fine copper gauze at each end as a cover. The pipe hangs by a metallic wire in a rearing bottle, in the bottom of which various chemical salts are placed to maintain the relative humidity desired (see Tsai, 1934 a, p. 7, Figure 2).

In each rearing pipe we placed five grains of rice for the oviposition and nutrition of the weevils. It was learned during a previous experiment that a bamboo rearing pipe is more suitable for the growth of storage insects in an incubator than a glass one.

To control the temperature during the experiments we used a multiple temperature incubator built at the National Agricultural Research Bureau by the senior author (see Tsai, 1934 b). It was constructed somewhat after the principle of Zwölfer's (1932) improved style of Williams' apparatus, the differences being that electricity is used for heating instead of gas and that a sheet of thick flannel is placed as a lining between the copper case and the cork wall of the incubator. These changes that the author has designed make it easier under the climatic conditions of China to produce and maintain temperatures from 2°C. to 45°C. The general and anatomical views of the incubator may be seen in Figures 1 and 2 of the paper on *Epidemiological Experiments with the Paddy Borer* (see Tsai 1935).



After Zwölfer (K. [illegible])

Figure 1 - Diagram showing the relative humidities maintained by various chemical salts at different temperatures

To produce and maintain the desired relative humidity, the authors applied the principle of the vapor pressure of supersaturated salt solutions, the following salts and water being used: $ZnCl_2$; $CaCl_2$ (crystal); $Ca(NO_3)_2$; NaCl; KCl; KNO_3; and water. These salts have also been used by Janisch (1930), Zwölfer (1931), and others in their experimental work. To maintain the correct relative humidity during the process of experimentation, it is necessary that these chemical salts, with the exception of both $ZnCl_2$ and $CaCl_2$, be dampened with a few drops of water before using and every few days thereafter during the experiment, especially at the high temperatures.

The possibility of maintaining a particular relative humidity by means of these salts in the limited air capacity of a rearing bottle is shown in Figure 1, which was used by Zwölfer with the exception of the KCl which was added by Janisch.

III. The Vital Optimum for Oviposition

The vital optimum for oviposition may be indicated by the maximal number of eggs deposited, and it is significant in relation to the population of a generation of insects. As regards the causal influences of oviposition, climatic conditions, especially both temperature and humidity, are the most important.

The rice weevil differs from the moth and other insects in having a long period of oviposition, continuing sometimes as long as, or longer than, one year. The total climatic influences during oviposition are, therefore, greater than in the case of those species which have a shorter period of oviposition. It results that, in even the same species of insects, the number of deposited eggs may differ according to the season or to the local climate. Certain results for 1934 are presented in Table 1. Figure 2 is drawn from Table 1 to show the effect on oviposition of the relation between temperature and humidity.

r. humidity / temperature	H_2O 100%	KNO_3 90-95%	KCl 80-85%	NaCl 72-78%	$Ca(NO_3)_2$ 50-62%	$CaCl_2$ 28-35%	$ZnCl_2$ 18%
35°C	—	—	—	—	—	—	—
31	17(.85)	3(.27)	6(.66)	2(.28)	—	—	—
28	60(1.37)	26(.79)	19(.73)	13(.50)	—	—	—
25	30(.47)	19(.43)	16(.42)	2(.33)	—	—	—
22	11(.20)	7(.53)	3(.37)	11(.17)	—	—	—
18	—	21(.95)	9(.42)	7(.17)	—	—	—
15	22(.30)	9(.15)	9(.47)	3(.17)	—	—	—
13	2	2	—	—	—	—	—
10	—	1	—	—	—	—	—
5	—	—	—	—	—	—	—

Table 1 - Showing the number of eggs deposited under various combinations of temperature and relative humidity (the figures in parentheses represent the number of eggs deposited per day)

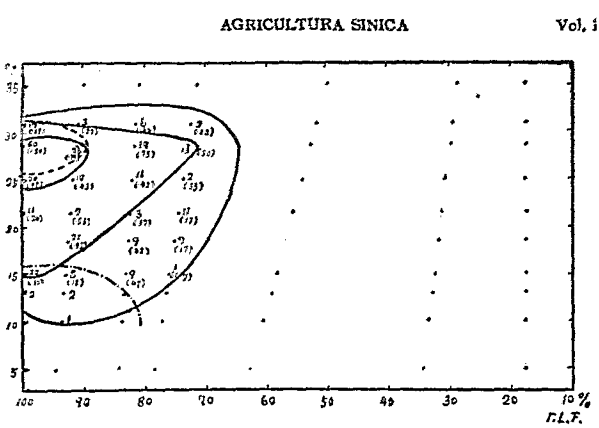


Figure 2 - A thermohygrogram showing conditions for oviposition. (The *puncta* represent the experimental weevils; the *arabic figures* indicate the number of deposited eggs, and the *figures inclosed in parentheses* represent the average number of eggs deposited per day; - - - : the maximal velocity of oviposition; —: the contour line of oviposition: —•—•—: the upper boundary of the area of maximal longevity; *°C:* temperature; *r. L. F.:* relative humidity)

Figure 2 shows clearly that the phenomena of oviposition vary according to temperature and relative humidity. If the temperature is between 24°C. and 29° C. and the humidity between 90% and 100%, the deposited eggs are likely to amount to the maximal number. The farther the conditions are from these, the fewer the eggs. From the standpoint of population, it will be recognized that a climatic condition ranging in temperature from 24° C. to 29° C. and from 90% to 100% in humidity is a vital optimum for oviposition. In other words, it may be said that, when such a climatic condition occurs, the weevils will increase greatly and consequently cause much damage to stored grain.

IV. The Maximal Velocity for Oviposition

As the eggs of the rice weevil ripen very slowly, the duration of oviposition is much greater than in the case of the moth and the butterfly; and the accumulated climatic influences are much more important, consequently, in the oviposition of the weevil. With a long period of oviposition, the number of eggs deposited is usually increased, but the velocity of oviposition is retarded.

Figures 2 and 3 show the influence of temperature and relative humidity on the number of eggs deposited and on the velocity of oviposition. The velocity may be determined by the following formula:

$$\frac{\text{Total eggs deposited}}{\text{Duration of oviposition in days}}$$

According to Figure 2, the area of maximal velocity lies between a temperature of 26° C. and 32° C. and a relative humidity of 90% to 100% (represented by a broken line). It may be considered that both a high temperature and a high humidity have a stimulative effect on the velocity of oviposition. Some authors, such as Janisch, consider that the climatic conditions favoring maximal velocity represent the "optimum" for development. The results of this experiment, however, show that such conditions do not produce a maximal number of eggs nor do they result in a high hatching percentage, and the size of the progeny is small; in fact, all results are unfavorable with regard to such characters. The authors, therefore, consider that the conditions favoring maximal velocity, at least for the weevil, which has a long period of oviposition, do not represent the "optimum" for development.

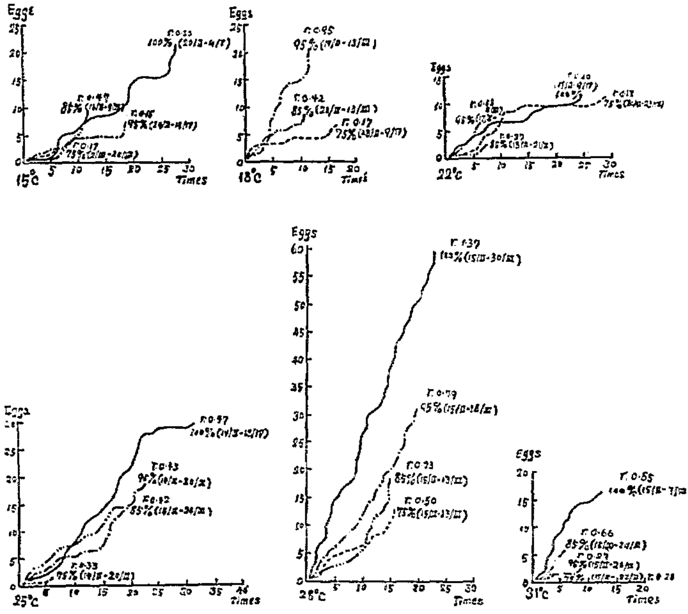


Figure 3 - Showing the influence on oviposition of various constant temperatures (15°, 18°, 22°, 25°, 28° and 31°C.) and of various relative humidities (75%-100%). *r.:* velocity of oviposition (average number of eggs deposited per day); the *duration of oviposition* is indicated by the dates in parentheses; *eggs:* accumulated number of eggs during oviposition; *times:* the number of inspections made during the experiment

V. Maximal Longevity

The lower temperatures usually tend to lengthen the life of organisms as metabolism is retarded and there is less energy lost. It is a common phenomenon to find maximal longevity among organisms in general at the lower temperatures although the upper and lower limits vary with different organisms. The maximal longevity of the rice weevil under various combinations of temperature and relative humidity is shown in Figure 4. In this figure we see that maximal longevity is found in an area with a temperature below 16° C. and with a relative humidity between 85% and 100%.

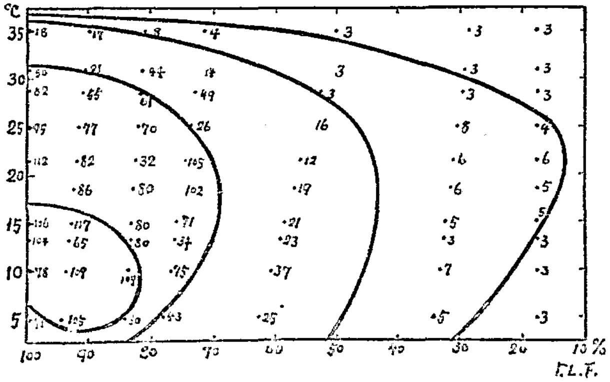


Figure 4 - Showing the maximal longevity of the rice weevil under various combinations of temperature (°C.) and relative humidity (r. L. F.)

VI. The Possible Range in Temperature and in Relative Humidity for Oviposition

According to the results of our experiments, we have found that the range in temperature for oviposition is from 10° C. to 35° C., while the range in relative humidity is from 60% to 100%. (See Figure 2). For practical purposes, then, we can consider that proper ventilation and a cool temperature in storage buildings are the most important factors for preventing oviposition.

VII. A Discussion of the Biological and Epidemiological Differences between the Rice Weevil and the Granary Weevil according to the Characteristics of Oviposition

Although the rice weevil and the granary weevil have very similar morphological characters, their physiological and biological differences are great. The weevils may be studied from the standpoint of *three vital phenomena* which are common to all organisms: the vital optimum, the maximal velocity, and the maximal longevity. The occurrence of these three vital phenomena in the granary weevil (according to the experiment of P. H. Tsai, 1934 a) is more definitely separated than their occurrence in the rice weevil according to the distribution on the thermohygrogram (Figure 2). The climatic conditions producing these three phenomena in the two species of weevils are indicated in Figure 5.

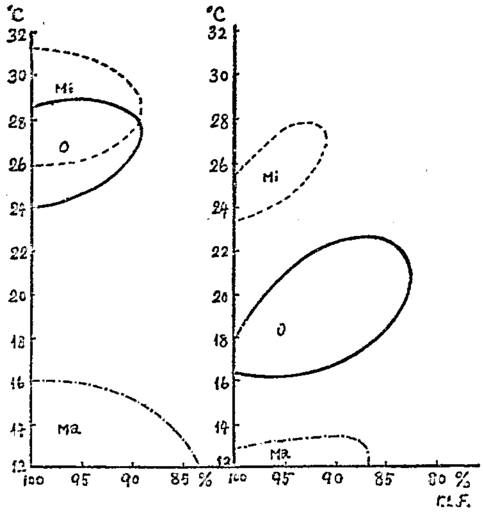


Figure 5 - A diagram indicating the climatic conditions producing the *three vital phenomena* in the rice weevil (left) and in the granary weevil (right). *O:* vital optimum for oviposition; *Mi:* maximal velocity for oviposition; *Ma;* maximal longevity of the weevils

From Figure 5, we can make the following comparative statements concerning the two species of weevils:

1. The position in the figure of the three vital phenomena for the rice weevil is somewhat higher than their positions in the case of the granary weevil, which indicates that the rice weevil thrives much better under warm conditions of locality, season, and the like than the granary weevil.

2. The climatic conditions producing the three vital phenomena in organisms vary according to species, and the variation is especially conspicuous with reference to the vital optimum. The vital optimum for the rice weevil has an upward tendency in the figure and coincides with a large part of the area representing maximal velocity (Figure 5, left). This indicates that the rice weevil is obviously a thermophilous insect and, consequently, is distributed more commonly in the southern parts of the globe than in the northern. In the case of the granary weevil (Figure 5, right) the three vital phenomena, however, are clearly separated from each other. The position of the vital optimum is lower than in the case of the rice weevil and, from this point of view, we can expect to find the granary weevil more often in the northern parts of the globe than the rice weevil.

According to the opinion of P. H. Tsai (1934 a) the vital optimum for tropical insects is somewhat higher than that for insects of temperate and sub-temperate zones and remains higher even when the insects are transferred to the other zones. The results of this experiment prove the above opinion to be an actual fact.

3. The optimal temperature for oviposition differs in the two species, but the relative humidity, however, is the same - a high humidity (above 85%) being necessary for oviposition in both species. Thus, from the standpoint of epidemiology, conditions favoring an outbreak of the rice weevil involve a rather high temperature with a high relative humidity, while for the granary weevil they involve a moderate temperature with a high relative humidity.

VIII. Résumé

The following information has been obtained from the experiments conducted:

1. A combination of temperature and relative humidity between 24° C. and 29° C./90% and 100% may be said to be a "vital optimum" (see Figure 5, left, *O*) for the oviposition of the rice weevil.

2. The climatic conditions producing the "maximal velocity" of oviposition (*Mi*) involve a temperature between 26° C. and 32° C. and a relative humidity between 90% and 100%.

3. The climatic conditions favoring "maximal longevity" (*Ma*) may be said to be a temperature below 16° C. and a relative humidity between 85% and 100%.

4. The possible range in temperature for oviposition is between 10° C. and 35° C. and in relative humidity between 60% and 100%.

5. As the positions of the vital optimum, the maximal velocity, and the maximal longevity in the case of the rice weevil are located somewhat higher than they are for the granary weevil on the temperature axis (see Figure 5), the distribution of the former species is more common in southern countries than that of the latter. The authors have found, however, that the rice weevil is distributed in China as far north as Kalgan and Sui-yuan (both about 41°N.) and as far south as Canton (23°N.).

6. From the above facts, we recognize that outbreaks of the rice weevil can be eliminated entirely either by maintaining a temperature in the storage house below 10° C. or above 35° C. or by maintaining a humidity less than 60%.

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米象產卵受溫濕度影響之實驗

蔡邦華　張延年

目　次

一. 緒言

米象 *Calandra oryzae* 亦有穀蛘,蛘子,蝦蚄,鉄嘴,地蚄,及四紋穀象等稱,爲赤褐色小形甲蟲,有長吻如象故名.具翅能飛.廣佈於世界各地,尤以暖熱帶,繁殖爲盛.在我國據作者所見,自察綏以南,各省所產概屬此種.其形態與穀象 *C. granaria* 甚似.但穀象缺翅,不能飛行,分佈區域偏於北部,生理性質亦多與米象異,翅鞘上缺四紋,尤易區別也.

二. 材料及方法

本項材料於二月上旬,採自中央大學農學院農場種子室內,繁殖於小麥種子者均爲成蟲,壽命雖不等,但其過去生活,因繁殖於同一室內,受自然界之影響,大旨亦相似也.

飼育前先分雌雄,然後擇體色相似之雌雄各一蟲,納於預製之飼育竹管內,該竹管以普通之筆管,截成長3 cm許爲之.爲便于飼育計,更括空其內孔,並於兩端蓋以銅紗帽,貫以銅絲,懸於調節濕氣之廣口瓶內,使與瓶內一定濕氣相接觸.又每管盛米五粒,以便蟲之產卵取食之

用

調節溫度裝置,用本所自製之複溫定溫箱(著者 1934 b).飼育溫度分下列十級5°,10°,13°,15°,18°,22°,25°,28°,31°及35°C.每級溫度下,更以七種濕氣爲一組飼育之.濕氣調節裝置,用四兩廣口玻璃瓶,瓶底塡以下列各項化學鹽類及水,利用其水蒸氣飽和壓力,以便於特定溫度下得相當之比較濕度,所謂化學鹽類及水者卽$ZnCl_2$(濕度約18%);$CaCl_2$(結晶性者濕度約28-35%); $Ca(NO_3)_2$(約48-60%); NaCl(約70-78%); KCl(約80-85%);K NO_3(約90-95%)及H_2O(100%)是也.但此項濕度之高低,隨溫度之變化而稍異,其變化之大略,可示如第一圖(見 176 頁).又爲便於米象之發育計,以每組七瓶,盛于一鐵絲籃內,籃之四週包以黑紙,以避光線

本項實驗,自二月中旬開始,每日鏡檢卵子之有無,至五月上旬第一次飼育結束,所得成績,因供試蟲生長不齊關係,誤差在所不免,但觀其大概情形,可摘錄如次:

本實驗進行中,關於卵子之檢查圖表之調製等工作,得湯楚雲楊慰慈兩小姐之助力不少,深致謝忱.

三· 米象之產卵生命最適度

產卵生命最適度云者,指產卵上受該項影響,能生出最多數孵化可能之卵子之溫濕度之組合而言也.亦稱產卵絕對數最大度.同一害蟲,繁殖力之大小與其產卵數之多少有深切之關係.故產卵數之檢查,乃爲實驗害蟲猖獗上之一重要問題.影響於產卵數最關深切者,厥惟氣候,而以溫度與濕度二者爲尤要.此層關係,對於米象類之產卵期間極長者,影響更甚.因其卵子之發育爲繼續性,受產卵期間氣候之支配甚大也,故同一種之害蟲,因春夏秋各季之氣候之不同,產卵數自亦有異.茲據試驗結果,製米象產卵之溫濕關係圖以明一般.(第二圖)

第二圖　米象產卵之溫濕關係圖(圖見 178 頁).縱軸表示溫度(°C).橫軸表示比較濕度(r. L. F.);圖中各圓點表示供試蟲飼育位置所記數字爲產卵總數.又數字之記於括弧中者,爲每日平均產卵數.虛線表示產卵最適度;虛點線表示壽命最長限界.

第二圖所示,實線表示產卵數量之等高線,斯項等高線呈同心圈形狀,即表示溫度之過高過低,與濕度之過燥過濕,均非所宜,而以位于中央之最小同心圈,其溫度在24-29°C濕度在90-100%之間者,爲產卵數量達於最多之範圍,換言之,自然界之氣候,一旦如達到此項範圍,對於米象之產卵最爲適當,亦即猖獗上主要之促成性條件也.

四. 米象之產卵速度最大度

米象類之產卵與蝶蛾類不同者,其產卵作用至屬緩慢,產卵期間顯形延長是也.因產卵期間之延長,致所受氣候之影響亦較長,影響所及,產卵總數,暨產卵速度,均生至大之懸殊.

產卵速度云者,乃以產卵日數,除產卵總數,所得之每日平均產卵數,(參照第三圖 r)如用等高線法圈定其產卵最速度,則如第二圖中虛線所示範圍,凡溫度在26-32°C濕度在90-100%之間者,即爲其產卵速度最大度.產卵速度最大度爲昆蟲受高溫高濕之刺戟,促成其代謝作用,而達於產卵上之最大速度.亦有誤稱爲最適度者,但非生理上正規現象,乃一時性之機械的刺戟作用,故僅以速度最大度名之也.

第三圖　各項定溫(15°, 18°, 22°, 25°, 28°, 及31°C)下米象產卵受各項濕度(75-100%)之影響. (圖見179頁) 縱軸表示產卵總數(Eggs); 橫軸表示一定時期之檢查次數(Times); 括弧中數字表示產卵期間; n表示每日平均產卵數.

五. 米象之生命期間最大度

低溫能延長生物之壽命,蓋生物之原形質受低溫之刺戟較少.凡在低溫狀態下者,其代謝作用極趨緩慢,體力之消耗尤少.故於壽命之維持甚屬適當.而生命期間最大度,即於此項條件下求得之.生命期間最大度,雖爲一般生物之普通現象,但其範圍之高低,與表現之緩急,則因生物種類而稍異.此項現象,在米象約位於溫度16°C以下,濕度85-100%之間.(參觀第二圖及第四圖)

第四圖米象生命期間與溫濕度之關係(數字表示生活日數(圖見180頁)

六. 米象產卵之可能範圍

據實驗成績,米象產卵之最低溫度爲 10°C 且同時須有充分濕氣(95%左右)之供給,始克產卵.較此溫度爲低或更爲乾燥時,則不能產卵.又高溫達 35°C 以上,空中濕氣在 60% 以下之乾燥狀態者.均能停止其產卵作用,故倉庫中之溫濕度,如在產卵可能範圍(參觀第二圖)以外時,均能防止米象之發生.此於倉庫設計時,對於換氣及保冷裝置,不可不特加注意也.

七. 由產卵生理而論米象與穀象之生物學上及猎獗學上之異同

米象與穀象,在形態上爲極近似之甲蟲.但在生理生態上則差異殊多.茲就產卵而論,觀第五圖所示,已可察知其大略矣.

第五圖 米象(左)及穀象(右)之生命最適度(0),產卵速度最大度(Mi);生命期間最大度(Ma)(圖見 181 頁)

上圖所示,米象穀象在產卵上均同具有三項不同之集中區域,(生命三現象)即作者(1934)所稱產卵速度最大度,產卵生命最適度及生命期間最大度是也.斯三者在穀象雖顯形分離,然在米象則生命最適度乃向高溫方面移動,其一部分範圍已與產卵速度最大度相重疊,在上述三項現象未得顯著分別時,此二者大有混視爲一之可能.今就溫度高低而論,則穀象之生命最適度位於 16-22°C 之間,米象則位於 24-29°C 之間.查斯項最適度之相差,有如斯之甚者,所以表示二者之分佈頗有不同也.因米象屬熱地性種類,其分佈範圍較近於熱帶,或亞熱帶地方.穀象屬溫帶或溫帶北部之昆蟲,其分佈自亦偏及於北方.故作者(1934 a)曾論其分佈關係謂「熱帶性昆蟲之生命最適度,不但其在熱帶之個體.爲位于較高之位置,即一旦向亞熱帶或溫帶地方移居而繁殖後,亦能保持其固有之較高之生命最適度焉」云.今證諸事實正相吻合.抑更有

詳者,如第五圖所示,米象不特生命最適度,所需溫度較穀象爲高.即其餘兩生命現象,如產卵速度最大度與生命期間最大度,亦均較穀象略高.此於生理上顯示米象有適於熱地繁殖之性質也.

就猖獗方面立論,二者在繁殖上所需最適溫度,雖有高低之別,但空中濕氣如不達於85%以上之高濕狀態時,則均難逞其繁殖之作用.又如空中濕氣低於50%者,對於米象穀象均同具有絕對防止其繁殖之作用.由以上種種情形而論,可知米象之猖獗條件,爲倉庫之高溫多濕,而穀象之猖獗條件則爲中庸溫度與多濕,是其不同耳.

八・ 結論

據以上實驗所得之結果列論如次:

1.米象產卵生命最適度,位於溫度24-29°C濕度90-100%之間.

2.米象產卵速度最大度,位於溫度26-32°C濕度90-100%之間.

3.米象生命期間最大度,位於溫度16°C以下濕度85-100%之間.

4.米象產卵可能範圍,開始產卵之低溫爲10°C(在95%濕氣下),停止產卵之高溫爲35°C,濕氣方面以60%之比較濕度爲開始產卵之最乾燥濕氣,凡空氣較此愈潮濕,則產卵作用,愈爲順適.

5.米象之生命最適度,產卵速度最大度,及生命期間最大度等所需溫度均較穀象爲高,此所以示其分佈偏於熱帶也.然在我國之分佈,據調査所得,北自綏遠,察哈爾,大同,北平等處,南至廣東均產之.

6.據上項實驗成績,凡倉庫中能保持濕氣在60%以下,溫度在10°C以下或35°C以上時,均能絕對防止米象之繁殖.

九・ 參考文件 (見第182至183頁)

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