EFFECT OF CONSTANT TEMPERATURE ON THE NYMPHAL DEVELOPMENT, LONGEVITY AND REPRODUCTION OF THE ORIENTAL PEA APHID, *APHIS CRACCIVORA* KOCH, FED ON CHEMICALLY DEFINED DIET

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INTRODUCTION

Since Mittler and Dadd (1962) first successfully reared the green peach aphid, *Myzus persicae* SULZER on a chemically defined diet, many attempts have already been made to feed various aphid species on a synthetic diet (Auclair and Cartier 1963, Kieckhefer and Derr 1967, Ehrhardt 1968 and Tahori and Hazan 1970). All these studies were conducted to investigate the relationship between nutrition and development of the aphid. It is well known that the environmental temperature to have profound influence on the development and life of aphid. But the effects of different constant temperatures on the development of aphid fed on synthetic diet have never been reported. The following experiments were conducted to determine the influence of various constant temperatures on the nymphal development, longevity and reproduction of the Oriental pea aphid *Aphis craccivora* KOCH fed on a synthetic diet.

MATERIALS AND METHODS

The aphids used in the present experiment were the offspring of the apterous females which had been reared continuously for more than three months on bean seedlings, *Vicia faba* L. at 20°C temperature, 70–80% relative humidity and 16 hours photoperiod. To obtain test aphids, ten new adult aphids from stock culture were placed on a container. After 16 hours more than fourty nymphs, produced during that time, were transferred to ten nymphs per new container with a fine brush. So, the test aphids had never been in contact with the bean seedling. The composition of the diet was based on the reports of Auclair (1965) and Dadd and Mittler (1966). Slightly modified diet was shown in Table 1. The diet was renewed once every day, and at the same time nymphal mortality, development, reproduction and longevity data were recorded. The artificial rearing apparatus of the aphid was shown in Fig. 1. At first, small square (2×2 cm) of parafilm was put on the upper end of a small glass tube (0.5×4 cm), which was pushed inward so that there was a dented space where a drop of diet (0.03 ml) was put, then a second

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TABLE 1. Composition of an artificial diet for rearing *A. craccivora*.

Amino acids	mg	Vitamins and others	mg
L-Alanine	100	L-Ascorbic acid	100
γ-Aminobutyric acid	10	Biotin	0.1
L-Arginine	270	Calcium pantothenate	5
L-Asparagine	550	Choline chloride	50.0
L-Aspartic acid	140	Folic acid	0.5
L-Cysteine	40	i-Inositol	50.0
L-Glutamic acid	140	Nicotinic acid	10.0
L-Glutamine	150	Pyridoxine HCl	2.5
Glycine	80	Riboflavin	0.5
L-Histidine	80	Thiamine HCl	2.5
L-Isoleucine	160		
L-Leucine	80		
L-Lysine HCl	240	Sucrose	15000
L-Methionine	80	Magnesium chloride $6H_2O$	200
L-Phenylalanine	80	Potassium phosphate monobasic	500
DL-Pipecolic acid HCl	10		
L-Proline	80	Cu disodium EDTA	0.4
L-Serine	80	Fe disodium EDTA	1.5
L-Threonine	140	Mn disodium EDTA	0.8
L-Tryptophan	80	Zn disodium EDTA	0.8
L-Tyrosine	40	water (deionized) to make 100 ml	
L-Valine	160	pH adjusted to 7.0 with KOH.	

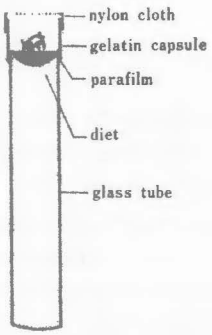

Fig. 1. Detailed view of the aphid-feeding apparatus.

piece of stretched parafilm was spread on the diet. The aphid cage was made of gelatin capsules (Eli Lilly Com. No. O).

The test aphids were placed in the cage, covered with a piece of nylon cloth to prevent them from escaping. Rearing was carried out at eleven different temperatures between 10° and 35°C under 16 hours photoperiod. Relative humidity was maintained between 70-80 % in each temperature. In the present experiment most of the test nymphs, matured at all temperatures except 12.5°C were apterous form. As a result, all the data herein refer to apterous females.

RESULTS

1. Nymphal development of apterous female

The relation between constant temperature and complete nymphal development of *A. craccivora* from the birth to the production of the first offspring is shown in Fig. 2. and Table 2. As temperature increased

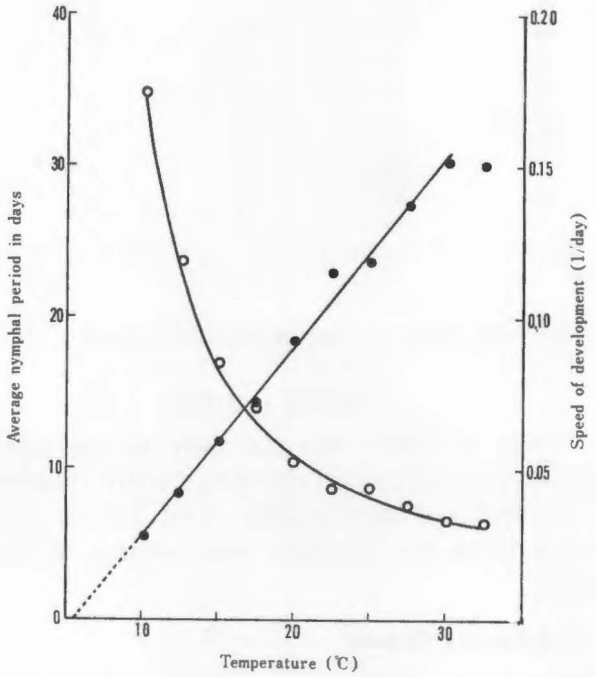

Fig. 2. Average nymphal period (open circles) and speed of development (closed circles) of *A. craccivora* at various constant temperatures.

from 10° to 30°C, the average developmental days gradually decreased from 35.0 days at 10°C to 6.6 days at 30°C. Beyond this temperature nymphal period does not decrease any more. At the temperature of 35°C, none of the nymphs used in the experiment attained adult stage. If the reciprocals of the average time required for the development at each temperature are plotted against temperature, the curve of the average developmental velocity can be obtained. It is generally known, within a medium temperature range, the velocity of development of insects in relation to temperature can be expressed as a straight line. In this experiment it will be seen that the developmental velocity curve obtained by plotting the reciprocal of the average duration of the nymphal period approches to a straight line between 10° and 30°C. At temperature above 30°C, the rate of development was decreased. By the method of

TABLE 2. Duration of nymphal period of *A. craccivora* at various constant temperatures.

Temperature (°C)	Initial number of aphid	Death rate (%)	Number of aphid matured		Average nymphal period of apterous (days)
			apterous	alatae	
35	20	100	—	—	—
32.5	20	60	8	0	6.63±0.32*
30	20	45	7	4	6.57±0.37
27.5	20	25	11	4	7.27±0.14
25	20	30	9	5	8.44±0.34
22.5	20	15	12	5	8.75±0.18
20	20	15	14	3	10.79±0.28
17.5	20	20	12	4	14.08±0.34
15	20	25	11	4	17.00±0.57
12.5	20	45	4	7	23.50±0.65
10	20	50	9	1	35.00±1.55

* Standard error

least squares from the data at temperatures between 10° and 30°C an equation

$$y = 0.0062x - 0.0332$$

was calculated. Data at 32.5°C was not used for the calculation of the line. This equation represents well the temperature-velocity relation, and the theoretical threshold of development to be 5.35°C, and the effective accumulated temperature for complete development of this species was 161.29 day-degrees.

2. Longevity of apterous female

The average number of days from birth to death of the aphids at each temperature between 10° and 35°C is shown in Table 3. The total

TABLE 3. Longevity of apterous female of *A. craccivora* at various constant temperatures.

Temperature (°C)	Number of aphids used	Longevity in days	
		Range	Average
35	10	1~ 7	4.3±0.67*
30	15	11~21	15.5±0.78
25	10	23~27	23.7±0.54
20	16	26~35	30.1±0.74
15	12	28~46	37.1±1.69
10	6	37~58	48.2±3.35

* Standard error

life period was also greatly influenced by the temperature. The longevity decreased fairly as the temperature became higher up to 35°C. Beyond

this temperature, however, all nymphs died before reaching the adult stage. The minimum life period was found only 1 day at 35°C, and the maximum was 58 days at 10°C.

3. Reproduction of apterous female

As is seen in the data of Table 4, the average total number of offspring was maximum at 20°C, at which temperature from 12 to 28

TABLE 4. Reproduction of apterous female of *A. craccivora* at various constant temperatures.

Temperature (°C)	Number of aphids used	Reproduction	
		Range	Average
35	10	—	—
32.5	10	0~ 5	2.4±0.54*
30	10	4~15	9.1±1.01
27.5	10	10~26	15.2±1.44
25	10	11~22	16.2±1.37
22.5	10	11~23	16.4±1.39
20	10	12~28	18.7±1.51
17.5	10	5~13	10.9±1.27
15	10	4~15	8.1±1.10
12.5	10	2~ 7	3.6±0.54
10	10	—	—

* Standard error

offspring per female were produced during the life time. There was no statistically significant difference in number of offspring produced per female in the range of temperature 20°-27.5°C. There was a decrease in reproduction from 20°C to both lower and higher temperatures, only 2.4 and 3.6 were produced at the temperature 32.5°C, and 12.5°C respectively. Reproduction ceased at a minimum temperature 10°C and maximum of 35°C.

DISCUSSION

The Oriental pea aphid, *Aphis craccivora* KOCH, which is found in the every continent of the world living principally on the leguminous plant. This aphid is also known as a vector of milk-vetch dwarf virus of the leguminous plant in Japan (Inouye at al. 1968). But there have been relatively few reports of its ecology. Last year the writer (1972) was successfully reared this species for 15 generations on chemically defined synthetic diet. Yet, the effect of various temperatures on the development of this species is by no means clearly known. This is the reason why the writer has undertaken the present study.

It is well known that the relation of the speed of development of insects to temperature is not expressed as a straight line, but a sigmoid curve throughout the whole range of temperature at which the development is possible. In this experiment at a temperature of 32.5°C, the speed of development was clearly decreased. At the increased temperature of 35°C, none of the nymphs used in the experiment attained adult stage and most of the nymphs died during the first or second instars. Taking these facts into consideration, the writer believes that in the present experiment the limit of high temperature for the nymphal development was between 32.5° and 35°C. It was not possible to determine the lowest temperature limit of nymphal development. Because the writer was not able to carry on rearing at a temperature lower than 10°C. But extrapolation of the temperature-velocity line to where it crosses the temperature axis gives the threshold of development of *A. craccivora* in this case, 5.35°C.

It is recognized that the value of 5.35°C is the theoretical one and not the temperature at which development actually ceases. The death rate occurred during the nymphal period is shown in Table 2, it shows that the death rate decreased from 10° to 20°C, and increased again until it reached 100 % at 35°C.

Judging from the death rate, it seems that the optimum temperature of *A. craccivora* lies somewhere between 17.5°–22.5°C.

According to Kawada (1971), the average nymphal period of plant-reared *A. craccivora* was four days shorter than that of a diet-reared aphid at 20°C. This result is evidently due to the difference of food. The diet used in the present experiment was thus a nutritionally poorer food than the host plant. The composition of the diet needs further modification to accelerate nymphal growth for this aphid. A similar phenomenon has been reported in other diet-reared aphids (Dadd and Mittler 1966, Akey and Beck 1972).

The temperature had also distinct effect on the number of offspring produced. The maximum number of offspring was produced at 20°C, temperature beyond 20°C there was a decrease in reproduction, with the increase in temperature the decrease in life-span was noted. Kenten (1955) reported that high temperature caused a reduction in size and lengthening of nymphal period of *Acythosiphon pisum* HARRIS, and both these characteristics were observed in the present experiments when *A. craccivora* was reared at temperature 32.5°C. Kawada (1964) found that *Lipaphis erysimi pseudobrassicae* DAVIS could develop but the number of offspring produced decreased markedly at 30°C. While Barlow (1962) reported that *Macrosiphum euphorbiae* THOMAS failed to develop completely at this temperature. *A. craccivora* therefore appears to be slightly more

resistant in high temperature than these species. This response to temperature may partly explain the wide distribution of this species in the world. But to solve this problem, the writer believes that more detailed studies on concerning environmental condition such as humidity, photoperiod, host plant and others would be necessary.

SUMMARY

The effect of constant temperature on the nymphal development, longevity and reproduction of the Oriental pea aphid, *Aphis craccivora* KOCH fed on artifical synthetic diet has been studied.

The relation between temperature and velocity of nymphal development was linear between 10° and 30°C. The theoretical threshold of development was 5.35°C, and the effective accumulated temperature necessary for complete development was 161.29 day-degrees on an average. The length of total life period decreased with rising temperature, the minimum being only 1 day at 35°C, and the maximum 58 days at 10°C. The greater number of offsprings per female was produced at medial temperature range 20° and 27.5°C than any other high or low temperature. The maximum number was 28 at 20°C, and minimum only 2 at 12.5°C. Reproduction ceased at 10° and 35°C, respectively.

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