INSECT POPULATION STUDIES.

III. Idea of Biograph and Biometer.

(Instruments for estimating Developmental Periods and Number of Generations of insects in Nature.)

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1. Introduction.

It is needless to discuss that temperature is the most important factor which determines the duration of various insect stages and consequently the number of generations of most insects (in fact of organisms in general) during a fixed period of time, other factors like humidity, light, etc. causing only a small difference specially during their non-limiting range. In the words of Bodenheimer (1938) 'The duration of life cycle depends on many environmental factors of which the chief one is always temperature. Humidity, quantity and quality of accessible food, etc. are other important factors, but for the normal life cycle of most animals their importance is small as compared with that of temperature. Other factors, however, may need to be used for local corrections of the pure temperature dependency'. Recognising this major importance of temperature, phenologists have been trying for centuries to establish such correct relationship between temperature and development of organisms as would enable estimations like calculation of duration of various insect stages corresponding to different temperatures. The oldest and simplest assumption is that a linear relation exists between temperature and average velocity of development or, in other words, the time required to complete the development at a particular temperature multiplied by the effective temperature * gives a constant product known as the *thermal constant* for the species. Mathematically this relation is also known as hyperbolic relation between temperature and developmental periods. This assumption forms the basis for what is commonly known as 'temperature-sum-rule', 'summing of temperatures', 'thermal summation', etc. according to which the daily effective temperature can be added from day to day and when the total reaches the value of thermal constant, it will indicate the completion of development.

The idea of thermal summation is now over two centuries old, Reaumur (1735) according to Shelford being 'commonly credited with being among the first to "sum" temperatures'. During this period the basic assumption of straight line relationship has been proved times over and again to be contrary to facts, and a number of more accurate hypotheses and methods of calculation have been put

* Effective temperature, according to definition, is equal to the actual temperature minus the lowest temperature called threshold at which development is perceptible.

forward by various workers including the present author but the following two practical disadvantages have persisted in all the later attempts:

(*a*) somewhat as expected the more accurate a method is, it is also the more complicated;

(*b*) almost all the later workers putting forward different hypotheses have given methods *only* for calculation of average developmental velocity corresponding to particular constant temperatures but they have not pointed out any means of estimating the developmental periods under day-to-day and hour-to-hour temperature fluctuation in nature which 'thermal summation' at least aims at.

Therefore partly due to what Bodenheimer calls 'mathematicophobia of most biologists' and partly due to very tempting utility of the process of thermal summation, the oldest hyperbolic assumption, despite its constant deviation from observed facts, still strongly holds the practical field of ecological investigation (*vide* Bodenheimer—1924, Zwolfer—1934). Shelford (1929, p. 183) while reviewing the subject of 'Animal in relation to temperature' comes to the conclusion: 'The idea now centuries old to the effect that temperature can be summed so as to give approximately the time of development of a particular organism, must be abandoned wherever accurate results are desired. This method is likely to fail more or less completely in the unusual seasons when accuracy is most desired.' But due to the practical utility of thermal summation Shelford had to maintain the same basic idea although he had to introduce some ingenious but laborious corrections for deviation from straight line relationship.

In order to overcome the disadvantages of later methods and hypotheses pointed out above, I am trying to put forward a simple device for adapting ordinary thermographs to what may aptly be called *Biographs* and *Biometers*. These instru-

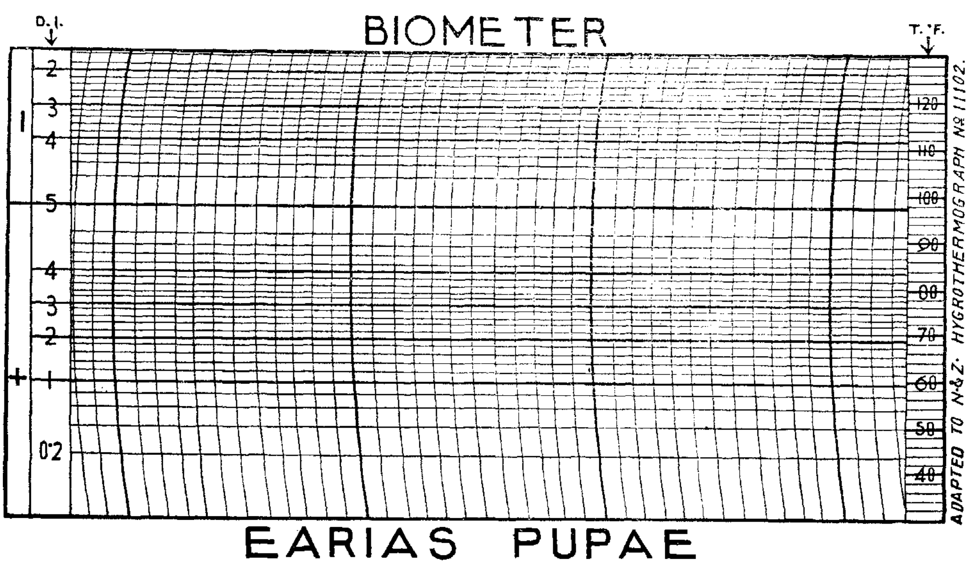

FIG. 1. A portion of biograph chart for *E. fabia* pupae, drawn separately for being printed on transparent sheet as Biometer. This chart was drawn to be used on hygrothermograph No. 11102 of Negretti & Zambra, London.

ments not only reduce to the minimum the difficulty of complicated calculations but they also make it easily possible to combine the basic idea of thermal summation with any of the more accurate hypotheses and methods, so that there may remain no further necessity of sticking to the erroneous assumption of hyperbolic relationship only for the sake of a number of practical applications (enumerated by Bodenheimer—1938, pp. 30-31) which are mere corollaries of thermal summation.

2. Biograph.

A biograph can be had merely by modifying the chart of a standard thermograph so that the horizontal lines of the chart, instead of showing different temperatures, may directly show the average velocity of development, corresponding to various temperatures calculated according to one of the more accurate methods.

Thus for constructing the biograph for the pupal period of *Earias fabia* represented in Fig. 1 the following temperatures (Table I: Columns 3 and 6) corresponding to different values of developmental index (Table I: Column 1) at intervals of 0·2 were calculated with the help of the following equation recently suggested by the present author (Pradhan, 1945):—

$$Y = Y_0 \, e^{-ax^2} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (I)^*$$

Then a thermograph chart adapted to a particular thermograph was drawn in which instead of drawing the horizontal lines at regular intervals representing full degrees, i.e. 42°, 44°, etc. as is the usual practice (as shown on the right hand side of Fig. 1), lines representing the temperatures shown in Table I, Cols. 3 and 6, i.e. 43·361°, 49·513°, 53·526°, etc. were drawn and labelled as representing the values of developmental indices, i.e. ·2, ·4, ·6, etc. respectively, as shown in Fig. 1. Now when this

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* Y = value of developmental index, i.e. reciprocal of developmental period corresponding to some particular temperature, say, $t°$; this reciprocal is, however, multiplied by 100 in order to get convenient values. Therefore $Y = 100/P$ in common calculations where P represents the developmental period, i.e. the time required to complete the development of a particular stage concerned.

Y_0 = highest possible value of developmental index for the species concerned. Let the temperature corresponding to Y_0 be T.

$\pm x = (T-t)$, i.e. $t = T \mp x$.

a = a constant.

e = base of Naperian logarithm = 2·718282 (constant).

When the constants of this equation were calculated taking $Y = 100/P$ we got for pupal period of *E. fabia* (calculations based on observations of Ahmad and Ghulamullah, 1939)

$$Y = 13{\cdot}69 e^{-{\cdot}001106\,(97{\cdot}288-t)^2} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (Ia)$$

i.e. the highest possible value of developmental index came to 13·69. Therefore for constructing the biograph we had to find out the temperatures corresponding to different values of Y at suitable intervals up to 13·69. Now for this purpose the value 13·69 is not suitable firstly because of its being indivisible by any suitable interval, say, ·2 or ·5, and secondly because of its being too large to be accommodated in a convenient width of biograph chart.

However, an arbitrary change in the value of Y_0 does not change the value of other constants of the equation. Thus if we take Y_0 to be equal to, say, 5, the change will only mean that the value of Y does not remain equal to $100/P$ as originally taken but it becomes $100/P \times 5/13{\cdot}69 = 36{\cdot}52/P$, i.e. the reciprocal of the developmental period is not multiplied by 100 but by another convenient number 36·52 which does not mean any deviation from the principle. Therefore for constructing the biograph Y_0 was taken to be 5 and the values of $\pm x$, i.e. $(97{\cdot}288-t)$ in Table I, Column 2, corresponding to different values of Y at intervals of 0·2 up to 5 were calculated with the equation

$$Y = 5e^{-0{\cdot}001106\,(97{\cdot}288-t)^2} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (Ib)$$

Then from each value of x the two values of temperatures (Table I, Cols. 3 and 6) corresponding to each value of Y were directly obtained by addition and subtraction.

Further, this biograph was to be adapted to a thermograph which was meant to record a range of temperature from 30°F to 130°F over a width of 7·7 cm. Thus taking 30°F as the base line, each degree above 30 was equivalent to 7·7/100, i.e. ·077 cm. Therefore for graphing the lines representing the temperatures shown in Table I, Cols. 3 and 6, first 30 was deducted from each temperature and then the remainder was multiplied by 0·077. The products thus obtained gave the distance from the base line of the lines representing the various temperatures given in Table I, Cols. 3 and 6.

TABLE I.

Summary of Calculations for constructing Biograph and Biometer.

Y	$\pm x$	t, i.e. $(97{\cdot}288-x)$			t, i.e. $(97{\cdot}288+x)$		
		t	$t-30$	$\cdot077(t-30)$	t	$t-30$	$\cdot077(t-30)$
1	2	3	4	5	6	7	8
0·2	53·927	43·361	13·361	1·0287	151·215	121·215	..
0·4	47·775	49·531	19·531	1·5021	145·063	115·063	..
0·6	43·762	53·526	23·526	1·8117	140·050	110·050	..
0·8	40·690	56·598	26·598	2·0483	137·978	107·978	Not
1·0	38·134	59·154	29·154	2·2444	135·422	105·422	needed.
1·2	35·908	61·380	31·380	2·4161	133·196	103·196	..
1·4	33·987	63·301	33·301	2·5639	131·275	101·275	..
1·6	32·085	65·203	35·203	2·7102	129·373	99·373	7·6509
1·8	30·381	66·907	36·907	2·8412	127·669	97·669	7·5214
2·0	28·774	68·514	38·514	2·9648	126·062	96·062	7·3961
2·2	27·233	70·055	40·055	3·0839	124·521	94·521	7·2778
2·4	25·752	71·536	41·536	3·1989	123·040	93·040	7·1647
2·6	24·305	72·983	42·983	3·3097	121·593	91·593	7·0517
2·8	22·887	74·401	44·401	3·4190	120·175	90·175	6·9443
3·0	21·483	75·805	45·805	3·5293	118·771	88·771	6·8360
3·2	20·082	77·206	47·206	3·6350	117·370	87·370	6·7282
3·4	18·664	78·624	48·624	3·7437	115·952	85·952	6·6177
3·6	17·227	80·061	50·061	3·8548	114·515	84·515	6·5088
3·8	15·747	81·541	51·541	3·9682	113·035	83·035	6·3944
4·0	14·198	83·090	53·090	4·0879	111·486	81·486	6·2747
4·2	12·557	84·731	54·731	4·2141	109·845	79·845	6·1488
4·4	10·745	86·543	56·543	4·3531	108·033	78·033	6·0089
4·6	8·678	88·610	58·610	4·5134	105·966	75·966	5·8492
4·8	6·084	91·204	61·204	4·7120	103·372	73·372	5·6494
5·0	0·000	97·288	67·288	5·1809	97·288	67·288	5·1809

NOTE.—Y represents developmental index as in Eq. I; x also represents the same as in that equation; t represents the temperature corresponding to Y and $\cdot077(t-30)$ represents the distance from the base line of the line representing t.

chart is put on the drum of the same thermograph* instrument to which it is adapted, the pen instead of marking the temperature at different times, shows directly the values of developmental index corresponding to different points in the whole range of temperature fluctuation. Thus the point O in Fig. 2, which would have shown on a thermograph chart that the temperature at 10 a.m. on Tuesday was 84·7°F, shows on this biograph that the average velocity of pupal development of *E. fabia* was 4·2 at 10 a.m. on Tuesday.

3. ESTIMATION OF DEVELOPMENTAL PERIODS.

Besides showing directly the value of developmental index at different times, the chief value of the biograph described above lies in the fact that it provides an

* If the biograph is to be used on a different thermograph instrument then its total width will have to be proportionately altered so as to fit in the other instrument. This can be done only by photographic magnification or reduction and does not need any fresh calculation or drawing. Of course for such photographic adaptations the drawing should not contain time lines.

easy and rather mechanical method for estimating the duration of different stages. It is clear that in the biograph the vertical scale represents the average velocity of development (developmental index) and the horizontal scale represents the time; therefore the area below the temperature (here velocity) tracing (*a*) in Fig. 2 can be

BIOGRAPH

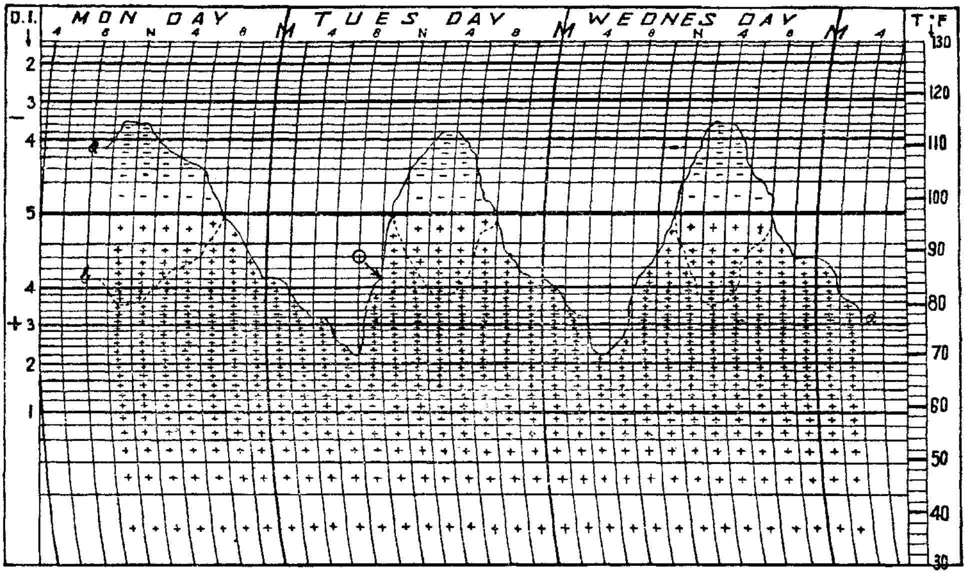

FIG. 2. Diagram illustrating the estimation of developmental periods by biographic method. The wavy solid line (*a*) represents the temperature tracing on biograph chart.

directly taken to give the product of developmental velocity and time, i.e. the amount of development itself. Thus the area enclosed by two consecutive midnight lines on the sides and between two consecutive thick horizontal lines representing whole number values of developmental index, e.g. between 1 and 2 D.I. or between 2 and 3 D.I., represents the amount of development completed in one day if the value of developmental index remains 1 D.I. throughout the twenty-four hours. Let us fix the amount of development represented by this area (somewhat rectangular space enclosed by comparatively thicker lines in Figs. 2 and 1) as unit which let us call *Biodiem*. Now, if the value of developmental index remains continuously 1 D.I. the full pupal development will take 36·52 days because as shown in footnote on page 303,

$$Y = 36{\cdot}52/P \text{ or } P = 36{\cdot}52\ Y = 36{\cdot}52 \times 1 = 36{\cdot}52 \text{ days.}$$

This means that the full pupal period is represented by 36·52 such areas as we have termed *Biodiem*. Further we see from Figs. 1 and 2 that each Biodiem consists of 60 small cells which may better be called *Biocells*. Thus with the biograph represented in Figs. 1 and 2 we can say that the pupal period of *E. fabia* is represented by 36·52 Biodiems or 36 Biodiems and about 31 Biocells or by 2,191 Biocells.

Now in order to determine the duration of pupal stage of *E. fabia* starting on any particular day, the only process which should be necessary is to count from that day onwards the number of Biodiems and Biocells below the temperature tracing, till the total comes to 36 Biodiems and 31 Biocells; the time and day when this total is reached will be the estimated time of emergence making allowance for individual variations. But, a close examination of the biograph will show that the value of developmental index rises with temperature up to 5 D.I. and then falls as gradually as it rose. Therefore if the temperature tracing (*a*) runs along the line of, say, 3 D.I. above the line of 5 D.I. it shows the same value of developmental index as if it were running along the line of 3 D.I. below the line of 5 D.I. Therefore as shown in Fig. 2 if the temperature tracing runs above the line of 5 D.I. as shown by the solid tracing (*a*) the area representing the amount of development will actually be below the dotted line (*b*); and it is clear that the area below the dotted line can be got by subtracting the area enclosed by the temperature tracing above the line of 5 D.I. from the area enclosed by the same tracing below the line of 5 D.I. Therefore the actual process of determining the pupal period of *E. fabia* comes to be:

A. The following record of Daily Biothermic Value * should be completed as a matter of routine every week when the biograph chart is changed:

(1) Starting, say, on the 1st of the month, count the number of biodiems and biocells below the temperature tracing (*a*) but from the base line below up to the line of 5 D.I. above and from midnight line before 1st to midnight line after 1st (cells marked by plus (+) in Fig. 2) and keep the total as plus quantity in Column 2 of Table II. For example, in Fig. 2 this plus quantity comes to be 2 complete Biodiems and 136 Biocells, i.e. 4 Bd, 16 Bc on Tuesday and 2 complete Biodiems and 135 Biocells, i.e. 4 Bd, 15 Bc on Wednesday.

(2) Then count the number of Biodiems and Biocells enclosed by the temperature tracing above the line of 5 D.I. (marked in Fig. 2 by minus signs) and keep this total as minus quantity in Column 3 of Table II. Thus in Fig. 2 this minus quantity comes to be nil Biodiems and 15 Biocells on Tuesday.

(3) The algebraic sum of the above plus and minus quantities will give the amount of development for the day, i.e. the Daily Biothermic Value entered in Column 4 of Table II. Thus in Fig. 2 the Daily Biothermic Value comes to be 4 Biodiems and 1 Biocell on Tuesday.

(4) From the next day onwards besides repeating the process 1 to 3, also keep in Column 5 of Table II, an up-to-date total of Daily Biothermic Values from the starting day onwards.

B. Having the above-mentioned records as shown in Table II, suppose we want to know the date of emergence of pupae pupating, say, on 17-4-44. For knowing this we have simply to add 36 Biodiems and 31 Biocells to the up-to-date total of Biothermic Value just before pupation and we shall get the up-to-date total of Biothermic Value just before emergence (Table III). Thus for the example taken we have 39 Bd and 36 Bc plus 36 Bd and 31 Bc equal to 76 Bd and 7 Bc. Now we have to follow down datewise and see when the up-to-date total reaches 76 Bd and 7 Bc. In Table II we find this total to be completing on 26-4-44; if we calculate up to nearest hour it will be 6 p.m. on 26-4-44. Therefore the expected date of emergence for the pupae pupating on 17-4-44 comes to be 26-4-44 at 6 p.m., i.e. the estimated pupal period of pupae pupating on 17-4-44 comes to be 9·75 days making allowance for individual variations. The actual emergence of the batch pupating on 17-4-44 did take place on 26-4-44 and 27-4-44. Thus in short

Up-to-date Total just before pupation + 36 Bd and 31 Bc
= Up-to-date Total just before emergence.

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* For convenience of terminology the everyday total number of Biodiems and Biocells is being designated by the term 'Daily Biothermic Value'.

TABLE II.

Daily Biothermic Values of Earias fabia *pupae from April 1944 to June 1945.*

(Figures for all the columns, i.e. 1–5, are given for April 1944 only; further on figures only of columns 1 and 5 are given.)

1	2		3		4		5		1	2		3		4		5	
Date.	+ Value.		− Value.		Daily Total.		Up-to-date Total.		Date.	+ Value.		− Value.		Daily Total.		Up-to-date Total.	
	Bd.	Bc.	Bd.	Bc.	Bd.	Bc.	Bd.	Bc.		Bd.	Bc.	Bd.	Bc.	Bd.	Bc.	Bd.	Bc.
1-4-44	2	7	..		2	7	2	7	16-4-44	3	6	..		3	6	39	36
2-4-44	2	0	..		2	0	4	7	17-4-44	3	24	..		3	24	43	0
3-4-44	1	22	..		1	22	5	29	18-4-44	3	8	..		3	8	46	8
4-4-44	1	37	..		1	37	7	6	19-4-44	3	10	..		3	10	49	18
5-4-44	1	46	..		1	46	8	25	20-4-44	3	33	..		3	33	52	51
6-4-44	1	51	..		1	51	10	43	21-4-44	3	46	..		3	46	56	37
7-4-44	1	57	..		1	57	12	40	22-4-44	4	1	..		4	1	60	38
8-4-44	2	16	..		2	16	14	56	23-4-44	4	11	0	2	4	9	64	47
9-4-44	2	36	..		2	36	17	32	24-4-44	4	20	0	2	4	18	69	5
10-4-44	3	6	..		3	6	20	38	25-4-44	4	3	..		4	3	73	8
11-4-44	3	8	..		3	8	23	46	26-4-44	4	20	0	1	4	19	77	27
12-4-44	3	23	..		3	23	27	9	27-4-44	4	15	0	1	4	14	81	41
13-4-44	3	11	..		3	11	30	20	28-4-44	4	7	..		4	7	85	48
14-4-44	3	6	..		3	6	33	26	29-4-44	4	7	0	1	4	6	89	54
15-4-44	3	4	..		3	4	36	30	30-4-44	4	13	0	2	4	11	94	05

Date.	Up-to-date Total.		Date.	Up-to-date Total.		Date.	Up-to-date Total.		Date.	Up-to-date Total.	
	Bd.	Bc.		Bd.	Bc.		Bd.	Bc.		Bd.	Bc.
1-5-44	4	9	28-5-44	119	54	23-6-44	101	28	2-8-44	8	18
2-5-44	8	7	29-5-44	124	42	24-6-44	106	15	3-8-44	12	33
3-5-44	12	3	30-5-44	129	16	25-6-44	111	00	4-8-44	16	33
4-5-44	16	5	31-5-44	133	58	26-6-44	115	11	5-8-44	20	25
5-5-44	20	21				27-6-44	119	13	6-8-44	24	39
6-5-44	24	42	1-6-44	4	30	28-6-44	123	40	7-8-44	28	46
7-5-44	29	6	2-6-44	8	56	29-6-44	127	57	8-8-44	32	46
8-5-44	33	25	3-6-44	13	17	30-6-44	132	15	9-8-44	37	16
9-5-44	37	40	4-6-44	16	39				10-8-44	41	16
10-5-44	42	10	5-6-44	20	27	1-7-44	4	44	11-8-44	45	22
11-5-44	46	38	6-6-44	24	30	2-7-44	10	27	12-8-44	49	36
12-5-44	50	58	7-6-44	28	42	3-7-44	14	54	13-8-44	53	53
13-5-44	55	22	8-6-44	33	7	4-7-44	19	25	14-8-44	57	37
14-5-44	59	47	9-6-44	37	43	5-7-44	23	32	15-8-44	61	11
15-5-44	64	10	10-6-44	42	10	Data absent from			16-8-44	65	15
16-5-44	68	45	11-6-44	46	50	6th to 24th; hence			17-8-44	69	19
17-5-44	73	17	12-6-44	51	50	onwards up-to-date			18-8-44	73	27
18-5-44	77	28	13-6-44	56	19	total from 25th.			19-8-44	77	54
19-5-44	81	40	14-6-44	60	47	25-7-44	3	48	20-8-44	82	25
20-5-44	85	54	15-6-44	65	12	26-7-44	8	10	21-8-44	86	56
21-5-44	90	7	16-6-44	69	47	27-7-44	12	40	22-8-44	91	19
22-5-44	94	28	17-6-44	74	25	28-7-44	16	51	23-8-44	95	42
23-5-44	98	36	18-6-44	78	46	29-7-44	20	39	24-8-44	100	6
24-5-44	102	53	19-6-44	83	11	30-7-44	24	54	25-8-44	104	36
25-5-44	107	4	20-6-44	87	28	31-7-44	29	35	26-8-44	108	57
26-5-44	111	20	21-6-44	92	00				27-8-44	112	53
27-5-44	115	33	22-6-44	96	46	1-8-44	4	19	28-8-44	116	39

TABLE II—*continued.*

Date.	Up-to-date Total. Bd.	Bc.
29-8-44	120	9
30-8-44	123	53
31-8-44	127	25
1-9-44	3	28
2-9-44	6	58
3-9-44	10	24
4-9-44	14	10
5-9-44	17	55
6-9-44	21	40
7-9-44	25	29
8-9-44	29	19
9-9-44	33	15
10-9-44	37	18
11-9-44	41	18
12-9-44	45	6
13-9-44	48	55
14-9-44	52	51
15-9-44	56	46
16-9-44	60	38
17-9-44	64	38
18-9-44	68	39
19-9-44	72	40
20-9-44	76	41
21-9-44	80	22
22-9-44	83	50
23-9-44	87	27
24-9-44	91	3
25-9-44	94	19
26-9-44	97	29
27-9-44	100	42
28-9-44	104	9
29-9-44	107	24
30-9-44	110	32
1-10-44	3	30
2-10-44	7	14
3-10-44	11	15
4-10-44	14	49
5-10-44	18	43
6-10-44	22	33
7-10-44	26	19
8-10-44	28	57
9-10-44	31	42
10-10-44	34	13
11-10-44	36	34
12-10-44	38	54
13-10-44	41	19
14-10-44	43	51
15-10-44	46	16
16-10-44	48	43
17-10-44	51	33
18-10-44	54	24
19-10-44	57	15
20-10-44	59	25
21-10-44	61	39
22-10-44	64	4
23-10-44	66	35

Date.	Up-to-date Total. Bd.	Bc.
24-10-44	69	5
25-10-44	71	29
26-10-44	74	10
27-10-44	76	40
28-10-44	78	58
29-10-44	81	16
30-10-44	83	36
31-10-44	85	50
1-11-44	2	27
2-11-44	4	59
3-11-44	7	36
4-11-44	9	55
5-11-44	11	48
6-11-44	13	32
7-11-44	15	14
8-11-44	17	8
9-11-44	19	8
10-11-44	21	6
11-11-44	23	6
12-11-44	25	36
13-11-44	28	12
14-11-44	30	3
15-11-44	31	33
16-11-44	32	56
17-11-44	34	14
18-11-44	35	30
19-11-44	36	51
20-11-44	38	11
21-11-44	39	36
22-11-44	40	46
23-11-44	42	4
24-11-44	43	24
25-11-44	44	35
26-11-44	45	39
27-11-44	46	48
28-11-44	47	51
29-11-44	49	26
30-11-44	51	3
1-12-44	1	33
2-12-44	3	2
3-12-44	4	48
4-12-44	6	22
5-12-44	8	1
6-12-44	9	33
7-12-44	10	50
8-12-44	12	36
9-12-44	13	54
10-12-44	15	10
11-12-44	16	00
12-12-44	16	49
13-12-44	17	47
14-12-44	18	27
15-12-44	19	3
16-12-44	19	43
17-12-44	20	29
18-12-44	21	17

Date.	Up-to-date Total. Bd.	Bc.
19-12-44	22	5
20-12-44	22	51
21-12-44	24	9
22-12-44	25	21
23-12-44	26	26
24-12-44	27	10
25-12-44	27	54
26-12-44	28	46
27-12-44	29	34
28-12-44	30	34
29-12-44	31	24
30-12-44	32	16
31-12-44	32	50
1-1-45		32
2-1-45		59
3-1-45	1	29
4-1-45	1	53
5-1-45	2	15
6-1-45	2	33
7-1-45	2	55
8-1-45	3	19
9-1-45	3	44
10-1-45	4	2
11-1-45	4	16
12-1-45	4	33
13-1-45	5	5
14-1-45	5	43
15-1-45	6	18
16-1-45	6	54
17-1-45	7	29
18-1-45	8	13
19-1-45	9	11
20-1-45	10	5
21-1-45	10	55
22-1-45	11	54
23-1-45	12	53
24-1-45	13	52
25-1-45	14	50
26-1-45	15	49
27-1-45	16	39
28-1-45	17	37
29-1-45	18	14
30-1-45	18	56
31-1-45	19	36
1-2-45		40
2-2-45	1	25
3-2-45	2	16
4-2-45	3	2
Data from 5th to 12th absent; 6 Bd, 31 Bc, are interpolated for these dates, and added to give total for 12th.		
12-2-45	9	33
13-2-45	10	42

Date.	Up-to-date Total. Bd.	Bc.
14-2-45	11	44
15-2-45	12	42
16-2-45	13	53
17-2-45	15	12
18-2-45	16	15
19-2-45	17	23
20-2-45	18	39
21-2-45	19	45
22-2-45	21	6
23-2-45	22	22
24-2-45	23	52
25-2-45	25	45
26-2-45	27	35
27-2-45	29	30
28-2-45	31	36
1-3-45	2	7
2-3-45	4	31
3-3-45	6	20
4-3-45	7	15
5-3-45	7	53
6-3-45	8	41
7-3-45	9	48
8-3-45	11	8
9-3-45	12	40
10-3-45	14	28
11-3-45	16	22
12-3-45	18	18
13-3-45	20	37
14-3-45	23	26
15-3-45	26	14
16-3-45	29	21
17-3-45	32	37
18-3-45	35	41
19-3-45	38	32
20-3-45	41	9
21-3-45	43	36
22-3-45	46	30
23-3-45	49	20
24-3-45	52	21
25-3-45	55	29
26-3-45	57	56
27-3-45	60	18
28-3-45	62	53
29-3-45	65	36
30-3-45	68	35
31-3-45	71	53
1-4-45	2	7
2-4-45	4	12
3-4-45	6	13
4-4-45	8	22
5-4-45	11	7
6-4-45	14	36
7-4-45	17	37
8-4-45	20	11
9-4-45	23	10
10-4-45	26	16

TABLE II—*continued.*

Date.	Up-to-date Total.		Date.	Up-to-date Total.		Date.	Up-to-date Total.		Date.	Up-to-date Total.	
	Bd.	Bc.		Bd.	Bc.		Bd.	Bc.		Bd.	Bc.
11-4-45	29	29	28-4-45	92	13	14-5-45	56	26	31-5-45	130	40
12-4-45	32	50	29-4-45	95	58	15-5-45	60	51			
13-4-45	36	16	30-4-45	99	53	16-5-45	65	29	1-6-45	4	29
14-4-45	40	1				17-5-45	70	00	2-6-45	8	47
15-4-45	43	53	1-5-45	4	6	18-5-45	73	55	3-6-45	13	14
16-4-45	47	46	2-5-45	8	21	19-5-45	78	4	4-6-45	17	36
17-4-45	52	15	3-5-45	12	12	20-5-45	82	20	5-6-45	22	2
18-4-45	56	4	4-5-45	15	57	21-5-45	87	12	6-6-45	26	41
19-4-45	59	46	5-5-45	19	48	22-5-45	91	37	7-6-45	31	19
20-4-45	63	22	6-5-45	23	49	23-5-45	95	56	8-6-45	35	56
21-4-45	66	8	7-5-45	28	9	24-5-45	99	59	9-6-45	40	7
22-4-45	70	15	8-5-45	32	23	25-5-45	103	52	10-6-45	44	15
23-4-45	74	20	9-5-45	36	18	26-5-45	108	25	11-6-45	48	16
24-4-45	78	17	10-5-45	40	16	27-5-45	112	40	12-6-45	52	21
25-4-45	81	21	11-5-45	44	11	28-5-45	117	29	13-6-45	56	50
26-4-45	84	59	12-5-45	48	23	29-5-45	121	51	14-6-45	60	51
27-4-45	88	33	13-5-45	52	30	30-5-45	126	21	15-6-45	65	12

4. Estimation of Number of Generations.

The principle illustrated with the help of the biograph for pupal period is equally applicable to the duration of full life cycle which being known the number of generations in a given period of time can be directly calculated.

5. Biometer.

Biometer is only a biograph chart drawn on a transparent plate of celluloid or glass or printed as positive on a photographic film which can be superimposed

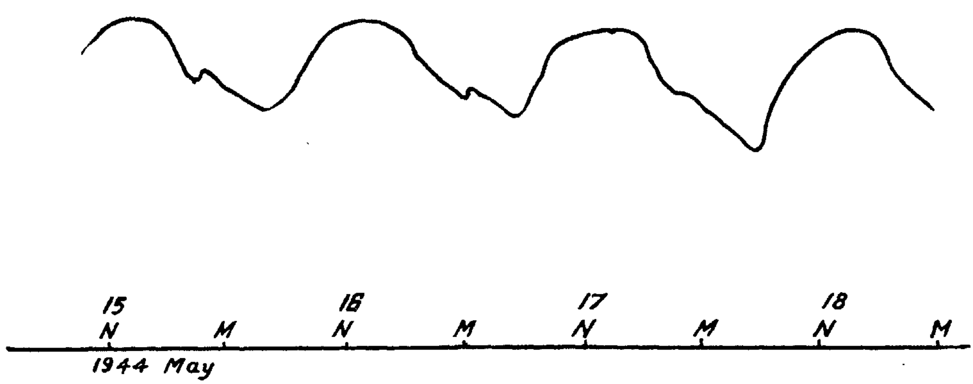

FIG. 3. Thermograph temperature tracing on plain paper. The tracing was transferred to a separate paper and specially inked before photographing.

over the thermograph records. By this device the idea of biographic method of estimation of developmental periods can be applied even to past thermographic records. Moreover the same thermographic record can be used to study a number of species by superimposing their respective biometers in turn.

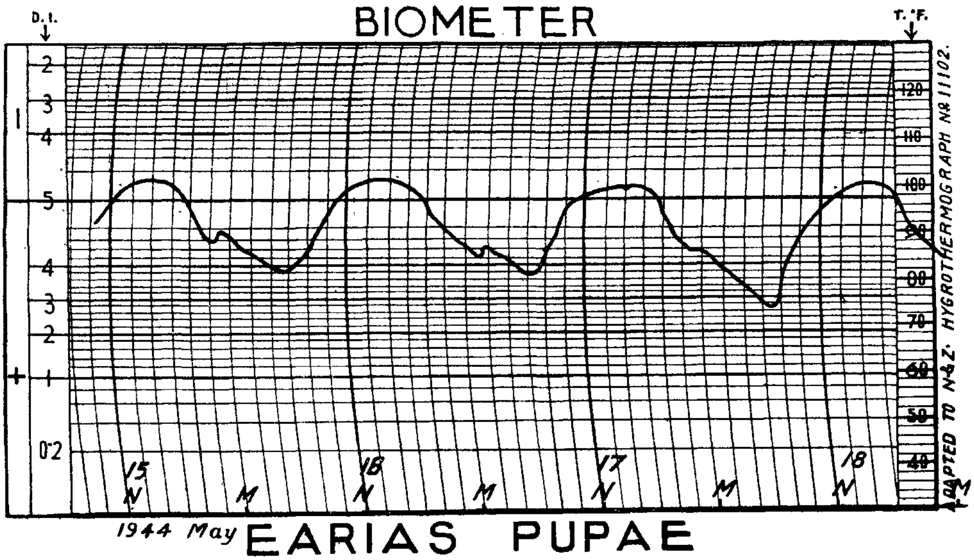

FIG. 4. Photograph taken after superimposing the transparent biometer (transparent print of Fig. 1) over thermograph tracing (Fig. 3).

6. Comparison of Estimated and Observed Values.

Table III gives a comparison of pupal periods determined experimentally with those estimated by biometric method. The actual values were determined by rearing pupae of *E. fabia* in a field laboratory under as natural conditions as possible. The estimations were made with the help of a biometer drawn on a celluloid sheet which was superimposed over the records of a thermograph which had been working near the rearing cages in the field laboratory. Table II was completed first and then with its help the Columns 2 and 3 of Table III were filled up.

It is intended, in due course, to compare the observed values of developmental periods in nature with estimations by all the different methods suggested so far. For the present, however, it will be seen that the agreement is more than ordinarily expected specially in view of the numerous disturbing factors involved in nature. Moreover, the present contribution is not the result of specially planned experiments; it is only a preliminary attempt to test the idea of biograph and biometer with the help of data collected for a variety of purposes during the course of general exploration of the problem of fluctuation of insect population. Consequently a number of possible causes of discrepancy have been present in the estimations given here. Therefore it is all the more gratifying that a fairly satisfactory agreement has been obtained between theory and observation. Some of the possible causes of error not avoided in the present estimations are:

(1) The biograph is based on Eq. I the constants of which were calculated from the data on developmental periods obtained when the larvae were throughout fed on *Bhindi* and not on cotton as was done in the experimental rearings reported herein.

(2) Equation I is based on data averaged for three grades of saturation deficiency, i.e. 0 S.D. and 13 S.D. and 14 S.D., but no other correction for changes in humidity was made in these estimations.

(3) The biometer used was drawn with hand on a celluloid sheet and cannot be taken to be quite free from errors of drawing, etc.

(4) The thermograph instrument, the records of which were used, has not been running very accurately.

TABLE III.

Estimation of pupal periods of E. fabia *by biometric method, and comparison of estimated and observed values.*

1	2				3		4			5		6
Date of Pupation.	Up-to-date Total: Before Pupation. A		Up-to-date Total: Before Emergence. B		Date and Time when pupal development should be completed.		Observed dates of Emergence and Number emerged.			Pupal Period in Days (Average). Obsd. A	Pupal Period in Days (Average). Estd. B	Remarks.
	Bd.	Bc.	Bd.	Bc.	Date.	Time.	Date.	♂	♀	A	B	
5-4-44	7	6	43	37	18-4-44	8 a.m.	19-4-44	0	1	14·00	13·33	
8-4-44	12	40	49	11	19-4-44	11 p.m.	18-4-44	0	1	11·50	11·45	
							21-4-44	0	1			
12-4-44	23	46	60	17	22-4-44	10 p.m.	22-4-44	0	1	10·00	10·42	
14-4-44	30	20	66	51	24-4-44	12 a.m.	25-4-44	0	1	11·00	10·50	
17-4-44	39	36	76	7	26-4-44	6 p.m.	26-4-44	0	1	9·50	9·75	
							27-4-44	1	0			
18-4-44	43	0	79	31	27-4-44	1 p.m.	27-4-44	0	2	10·33	9·54	
							1-5-44	1	0			
19-4-44	46	8	82	39	28-4-44	8 a.m.	27-4-44	0	1	9·33	9·33	
							28-4-44	2	0			
20-4-44	49	18	85	49	29-4-44	0 a.m.	29-4-44	0	1	9·00	9·00	
21-4-44	52	51	89	22	29-4-44	9 p.m.	29-4-44	0	1	9·33	8·87	
							1-5-44	1	1			
22-4-44	56	37	93	8	30-4-44	5 p.m.	1-5-44	2	2	9·20	8·70	
							2-5-44	0	1			
23-4-44	60	38	97*	9	1-5-44	6 p.m.	1-5-44	1	0	8·83	8·75	*3Bd, 4Bc, in May
							2-5-44	3	2			
25-4-44	69	5	105*	36	3-5-44	9 p.m.	4-5-44	3	1	9·00	8·87	*11Bd, 31Bc ,,
26-4-44	73	8	109*	39	4-5-44	9 p.m.	6-5-44	1	1	10·00	8·87	*15Bd, 34Bc ,,
27-4-44	77	27	113*	58	5-5-44	9 p.m.	6-5-44	0	1	10·20	8·87	*19Bd, 53Bc ,,
							8-5-44	1	3			
2-5-44	4	9	40	40	10-5-44	4 p.m.	12-5-44	3	1	10·00	8·66	
5-5-44	16	5	52	36	13-5-44	10 a.m.	14-5-44	0	3	9·00	8·42	
6-5-44	20	21	56	52	14-5-44	10 a.m.	16-5-44	1	2	10·00	8·42	
7-5-44	24	42	61	13	15-5-44	10 a.m.	16-5-44	3	4	9·00	8·42	
8-5-44	29	6	65	37	16-5-44	8 a.m.	16-5-44	3	5	8·43	8·33	
							17-5-44	3	3			
9-5-44	33	25	69	56	17-5-44	7 a.m.	17-5-44	1	5	8·60	8·29	
							19-5-44	2	1			
10-5-44	37	40	74	11	18-5-44	8 a.m.	20-5-44	1	0	10·00	8·33	
11-5-44	42	10	78	41	19-5-44	9 a.m.	19-5-44	1	1	8·00	8·37	
16-5-44	64	10	100	41	24-5-44	1 p.m.	25-5-44	1	1	9·33	8·54	
							26-5-44	0	1			
30-5-44	124	42	161*	13	7-6-44	4 p.m.	8-6-44	0	1	9·00	8·66	*21Bd, 15Bc, in June.
5-6-44	16	39	53	10	13-6-44	8 a.m.	12-6-44	0	2	7·00	8·33	
6-6-44	20	27	56	58	14-6-44	3 a.m.	14-6-44	0	2	8·00	8·12	
9-6-44	33	7	69	38	16-6-44	11 p.m.	16-6-44	1	0	7·00	7·96	
27-6-44	115	11	151*	42	5-7-44	0 a.m.	4-7-44	0	1	8·50	8·00	*19Bd, 27Bc, in July.
							5-7-44	0	1			
25-7-44	0	0	36*	31	2-8-44	12 a.m.	2-8-44	0	1	8·00	8·50	*6Bd, 9Bc, in Aug.
26-7-44	3	48	40*	19	3-8-44	2 p.m.	2-8-44	0	1	7·00	8·58	*10Bd, 44Bc ,,
27-7-44	8	10	44*	41	4-8-44	3 p.m.	4-8-44	2	1	8·00	8·62	*15Bd, 6Bc ,,

TABLE III—*continued.*

1	2				3		4			5		6
Date of Pupation.	Up-to-date Total: Before Pupation. A		Up-to-date Total: Before Emergence. B		Date and Time when pupal development should be completed.		Observed dates of Emergence and Number emerged.			Pupal Period in Days (Average).		Remarks.
	Bd.	Bc.	Bd.	Bc.	Date.	Time.	Date.	♂	♀	Obsd. A	Estd. B	
28-7-44	12	40	49*	11	5-8-44	7 p.m.	4-8-44	0	1	7·00	8·79	*19Bd, 36Bc, in Aug.
31-7-44	24	54	61*	25	8-8-44	7 p.m.	7-8-44	1	1	7·00	8·79	*31Bd, 50Bc ,,
8-8-44	28	46	65	17	17-8-44	0 a.m.	15-8-44	0	2	7·00	9·00	
12-8-44	45	22	81	53	20-8-44	9 p.m.	19-8-44	0	1	7·50	8·87	
							20-8-44	0	1			
14-8-44	53	53	90	24	22-8-44	7 p.m.	22-8-44	0	1	8·00	8·79	
15-8-44	57	37	94	8	23-8-44	3 a.m.	24-8-44	0	1	9·00	8·62	
18-8-44	69	18	105	49	26-8-44	8 a.m.	28-8-44	1	0	10·00	8·33	
19-8-44	73	27	107	58	27-8-44	6 a.m.	28-8-44	1	0	9·00	8·25	
28-8-44	112	53	149*	24	7-9-44	1 a.m.	5-9-44	1	2	8·00	10·04	*21Bd, 45Bc, in Aug.
29-8-44	116	39	153*	10	8-9-44	2 a.m.	5-9-44	1	1	7·66	10·08	*25Bd, 45Bc ,,
							7-9-44	1	0			
30-8-44	120	9	156*	40	8-9-44	12 p.m.	7-9-44	1	0	8·75	10·00	*29Bd, 15Bc ,,
							8-9-44	1	0			
2-9-44	3	28	39	59	11-9-44	4 p.m.	11-9-44	1	2	9·00	9·66	
4-9-44	10	24	46	55	13-9-44	12 a.m.	13-9-44	1	0	9·00	9·50	
5-9-44	14	10	50	41	14-9-44	12 a.m.	14-9-44	2	3	9·00	9·50	
6-9-44	17	55	54	26	15-9-44	11 a.m.	14-9-44	3	1	8·00	9·45	
7-9-44	21	40	58	11	16-9-44	9 a.m.	15-9-44	1	3	8·20	9·37	
							16-9-44	1	0			
8-9-44	25	29	62	0	17-9-44	9 a.m.	18-9-44	2	3	10·16	9·37	
							19-9-44	0	1			
11-9-44	37	18	73	49	20-9-44	8 a.m.	18-9-44	2	2	7·63	9·33	
13-9-44	45	6	81	37	22-9-44	10 a.m.	19-9-44	2	0	7·33	9·42	
							21-9-44	1	3			
14-9-44	48	55	85	26	23-9-44	12 a.m.	22-9-44	0	1	8·50	9·50	
							23-9-44	1	0			
15-9-44	52	51	89	22	24-9-44	1 p.m.	23-9-44	1	2	8·00	9·54	
16-9-44	56	46	93	17	25-9-44	4 p.m.	23-9-44	0	1	7·00	9·66	
18-9-44	64	38	101	9	28-9-44	6 a.m.	26-9-44	0	3	8·50	10·25	
							28-9-44	1	0			
19-9-44	68	39	105	10	29-9-44	10 a.m.	28-9-44	0	1	9·00	10·42	
21-9-44	76	40	113*	11	1-10-44	6 p.m.	1-10-44	0	1	10·60	10·75	*2Bd, 39Bc, in Oct.
							2-10-44	0	2			
22-9-44	80	22	116*	53	2-10-44	6 p.m.	2-10-44	0	1	10·00	10·75	*6Bd, 21Bc ,,
23-9-44	83	50	120*	21	3-10-44	2 p.m.	3-10-44	1	1	10·00	10·58	*9Bd, 49Bc ,,
25-9-44	91	3	127*	34	5-10-44	2 p.m.	5-10-44	1	2	10·00	10·58	*17Bd, 2Bc ,,
28-9-44	100	42	137*	13	8-10-44	5 a.m.	9-10-44	4	4	11·00	10·20	*26Bd, 4Bc ,,
29-9-44	104	9	140*	40	9-10-44	12 a.m.	9-10-44	1	1	10·00	10·50	*30Bd, 8Bc ,,
30-9-44	107	24	143*	55	10-10-44	3 p.m.	11-10-44	1	0	11·00	10·62	*33Bd, 23Bc ,,
2-10-44	3	30	40	1	13-10-44	1 p.m.	12-10-44	0	2	10·60	11·54	
							13-10-44	3	0			
4-10-44	11	15	47	46	16-10-44	4 p.m.	17-10-44	0	1	13·00	12·66	
5-10-44	14	49	51	20	17-10-44	9 p.m.	17-10-44	0	2	12·50	12·87	
							18-10-44	0	2			
6-10-44	18	43	55	14	19-10-44	11 a.m.	19-10-44	0	1	13·00	13·45	
7-10-44	22	33	59	4	20-10-44	7 p.m.	20-10-44	5	4	13·20	13·79	
							21-10-44	1	1			
9-10-44	28	57	65	28	23-10-44	2 p.m.	21-10-44	1	3	12·40	14·58	
							23-10-44	1	0			

TABLE III—*continued.*

1	2				3		4			5		6
Date of Pupation.	Up-to-date Total. Before Pupation. A		Before Emergence. B		Date and Time when pupal development should be completed.		Observed dates of Emergence and Number emerged.			Pupal Period in Days (Average). Obsd. A	Estd. B	Remarks.
	Bd.	Bc.	Bd.	Bc.	Date.	Time.	Date.	♂	♀	A	B	
11-10-44	34	13	70	44	25-10-44	4 p.m.	24-10-44	0	2	13·50	14·66	
							25-10-44	0	2			
12-10-44	36	34	73	5	26-10-44	3 p.m.	25-10-44	0	1	13·50	14·62	
							26-10-44	0	1			
13-10-44	38	54	75	25	27-10-44	1 p.m.	26-10-44	0	1	13·50	14·54	
							27-10-44	0	1			
14-10-44	41	19	77	50	28-10-44	12 a.m.	28-10-44	2	4	14·00	14·50	
17-10-44	48	43	85	14	31-10-44	4 p.m.	30-10-44	5	8	13·00	14·66	
18-10-44	51	33	88*	4	1-11-44	8 p.m.	1-11-44	1	0	14·00	14·83	*2Bd, 14Bc, in Nov.
20-10-44	57	15	93*	46	4-11-44	7 a.m.	4-11-44	1	1	15·00	15·29	*7Bd, 56Bc ,,
21-10-44	59	25	95*	56	5-11-44	5 a.m.	4-11-44	0	1	14·00	15·20	*10Bd, 6Bc ,,
23-10-44	64	4	100*	35	7-11-44	4 p.m.	7-11-44	0	2	15·00	15·66	*14Bd, 45Bc ,,
24-10-44	66	35	103*	6	9-11-44	3 a.m.	9-11-44	1	0	16·00	16·12	*17Bd, 16Bc ,,
25-10-44	69	5	105*	36	10-11-44	11 a.m.	11-11-44	0	1	17·00	16·45	*19Bd, 46Bc ,,
27-10-44	74	10	110*	41	12-11-44	5 p.m.	13-11-44	0	2	17·00	16·70	*24Bd, 51Bc ,,
30-10-44	81	16	117*	47	16-11-44	11 a.m.	15-11-44	0	3	16·80	17·45	*31Bd, 57Bc ,,
							17-11-44	2	0			
1-11-44	0	0	36	31	19-11-44	5 p.m.	16-11-44	0	1	16·60	18·70	
							17-11-44	0	1			
							20-11-44	0	1			
4-11-44	7	36	44	7	25-11-44	2 p.m.	28-11-44	1	1	24·00	21·58	
6-11-44	11	48	48	19	29-11-44	12 a.m.	1-12-44	1	0	27·20	23·50	
							4-12-44	1	2			
7-11-44	13	32	50	3	30-11-44	12 a.m.	1-12-44	0	1	24·00	23·50	
13-11-44	25	36	62*	7	8-12-44	9 a.m.	12-12-44	1	0	29·00	25·37	*11Bd, 4Bc, in Dec.
14-11-44	28	12	64*	43	9-12-44	7 p.m.	8-12-44	0	1	24·00	25·79	*13Bd, 4Bc ,,
20-11-44	36	51	73*	22	20-12-44	12 a.m.	2-1-45	1	0	43·00	30·50	*22Bd, 19Bc ,,
24-11-44	42	4	78*	35	25-12-44	1 p.m.	19-1-45	1	0	56·00	31·54	*27Bd, 32Bc ,,
27-11-44	45	39	82*	10	29-12-44	2 p.m.	22-1-45	0	1	56·00	32·58	*31Bd, 7Bc ,,
28-11-44	46	48	83*	19	31-12-44	0 a.m.	24-1-45	1	0	57·00	33·00	*32Bd, 16Bc ,,
30-11-44	49	26	85*	57	5-1-45	1 p.m.	26-1-45	1	0	57·00	36·54	*2Bd, 4Bc, in Jan.
4-12-44	4	48	41	19	19-1-45	11 a.m.	4-2-45	1	0	60·00	46·45	*8Bd, 29Bc ,,
8-12-44	10	50	47	21	25-1-45	4 p.m.	19-2-45	0	0	73·00	46·66	*14Bd, 31Bc ,,
23-12-44	25	21	61*	52	12-2-45	8 p.m.	28-2-45	1	0	67·00	50·83	*9Bd, 24Bc, in Feb.
10-4-45	23	10	59*	41	19-4-45	11 p.m.	20-4-45	0	1	10·00	9·96	
26-4-45	81	21	117*	52	5-5-45	3 p.m.	6-5-45	1	0	10·00	9·62	*17Bd, 59Bc, in May
1-5-45	0	0	36	31	10-5-45	1 a.m.	10-5-45	1	0	9·50	9·04	
							11-5-45	1	0			
4-5-45	12	12	48	43	13-5-45	2 a.m.	13-5-45	0	2			
							14-5-45	3	0	9·60	9·08	
5-5-45	15	57	52	28	13-5-45	12 p.m.	13-5-45	0	1	8·00	9·00	
8-5-45	28	9	64	40	16-5-45	8 p.m.	18-5-45	0	2	10·00	8·83	
9-5-45	32	23	68	54	17-5-45	7 p.m.	19-5-45	1	0	10·50	8·79	
							20-5-45	1	0			
10-5-45	36	18	72	49	18-5-45	6 p.m.	20-5-45	1	0	10·00	8·75	
11-5-45	40	16	76	47	19-5-45	5 p.m.	24-5-45	1	0	13·00	8·70	
12-5-45	44	11	80	42	20-5-45	3 p.m.	21-5-45	2	1	9·00	8·62	
13-5-45	48	23	84	54	21-5-45	12 a.m.	21-5-45	0	1	9·20	8·50	
							22-5-45	3	3			
							23-5-45	3	0			

TABLE III—*continued.*

1	2				3		4			5		6
Date of Pupation.	Up-to-date Total				Date and Time when pupal development should be completed.		Observed dates of Emergence and Number emerged.			Pupal Period in Days (Average).		Remarks.
	Before Pupation. A		Before Emergence. B							Obsd.	Estd.	
	Bd.	Bc.	Bd.	Bc.	Date.	Time.	Date.	♂	♀	A	B	
14-5-45	52	30	89	1	22-5-45	11 a.m.	22-5-45	1	1	8·80	8·45	
							23-5-45	9	1			
15-5-45	56	26	92	57	23-5-45	9 a.m.	24-5-45	1	2	9·00	8·37	
16-5-45	60	51	97	22	24-5-45	10 a.m.	24-5-45	0	2	9·00	8·42	
							25-5-45	2	0			
							27-5-45	0	1			
17-5-45	65	29	102	0	25-5-45	1 p.m.	26-5-45	2	1	9·40	8·54	
							27-5-45	0	2			
18-5-45	70	0	106	31	26-5-45	3 p.m.	26-5-45	1	0	9·30	8·62	
							28-5-45	1	1			
19-5-45	73	55	110	26	27-5-45	11 a.m.	31-5-45	0	1	12·00	8·45	
21-5-45	82	20	118	51	29-5-45	8 a.m.	30-5-45	1	1	9·00	8·33	
23-5-45	91	37	127	8	31-5-45	11 a.m.	2-6-45	1	0	10·00	8·45	
25-5-45	99	59	136*	30	2-6-45	9 a.m.	1-6-45	0	1	7·00	8·37	*5Bd, 50Bc, in June
26-5-45	103	52	140*	23	3-6-45	5 a.m.	4-6-45	0	1	9·00	8·20	*9Bd, 43Bc ,,
27-5-45	108	25	144*	56	4-6-45	5 a.m.	5-6-45	1	0	8·00	8·20	*14Bd, 16Bc ,,
30-5-45	121	51	158*	22	7-6-45	5 a.m.	9-6-45	0	1	10·00	8·20	*27Bd, 42Bc ,,

NOTE.—In practice it is convenient to calculate up-to-date totals from the 1st of each month separately. In doing so, however, it happens at times that up-to-date total previous to emergence exceeds the up-to-date total on the last date of the month. In such cases the up-to-date total of the last date of the month is deducted from the up-to-date total previous to emergence and the remainder is looked for in the up-to-date totals of the next month in order to find out the date of emergence. Sometimes even this remainder exceeds the up-to-date total of the last date of even next month. Then the up-to-date total of last date of next month is deducted from this first remainder and the second remainder is looked for in the third month. Thus take for example the batch pupating on 23rd April, 1944. The up-to-date total previous to emergence of this batch is calculated to be 97Bd, 9Bc. This figure exceeds up-to-date total on 30-4-44 which is 94Bd, 5Bc. Therefore we deduct 94Bd, 5Bc from 97Bd, 9Bc and we get 3Bd, 4Bc which is completed on 1-5-44.

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