

Thesis for the Degree of Ph.D.

The Life-History and Habits

of

Tortrix pronubana, Hb.,

With Special Reference to the

Larval and Pupal

Stages.

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The LIFE-HISTORY and HABITS of

TORTRIX PRONUBANA, Hb.,

(With Special Reference to the Larval
and Pupal Stages.)

Classification.

Order - Lepidoptera.
Group - Tortricina.
Family - Tortricidae.

I. Introductory.

Tortrix pronubana is first recorded as occurring in Britain in October 1905 when a single specimen of the moth was taken at Eastbourne (Adkin, 1905). It is recorded as having appeared in Guernsey in 1898 (Lowe, 1900). The moth is of Continental origin and was figured, without description, by Hübner in 1797 and 1830. According to Millière (1859), the species is a native of Southern Europe, Sicily, Corsica, Italy and Spain. Since its first appearance in Britain in 1905 - it is evident that the moth has firmly established itself in the South of England - gradually working its way North. Within the past three /

three or four years the species has become so abundant in the South as to prove harmful. In glass-houses at the Royal Botanic Gardens, Kew, serious damage is being done by the larvae to a great variety of plants.

The general life-history of the insect has been worked out by Adkin (1906 and 1908), who, however, has not given a detailed description of the larval stages. Accordingly, it was decided to conduct a further and more detailed investigation into its life-history and habits - with special reference to the larval and pupal stages. Material for the investigation was obtained from the Royal Botanic Gardens, Kew and the insect reared in the laboratory on carnation plants and privet cuttings. Carnations have been badly attacked by this insect in France, (Molinas 1914). The laboratory experiments, conducted in the Entomological Laboratory of the Forestry Commission at Kew, under the supervision of Dr. J. W. Munro, and also in Dr. R. Stewart MacDougall's Laboratory in the University of Edinburgh, were amplified and supplemented by observations made in the glass-houses at Kew.

Tortrix pronubana is an interesting example of an insect which has within recent years appeared in our country from the South, gradually establishing itself and spreading Northwards as it adapts itself to /

to its new environment and climatic conditions. At the present time its actual distribution in Britain is not known but it would appear that, in the London district, where the work was carried out, the moth is present in large numbers, in the open, South of the Thames - while, North of the river, although to be found it does not occur abundantly. Continental references to T. pronubana state that the larva is polyphagous. This is amply borne out under glass at Kew, but in the open the larvae are found abundantly chiefly on privet, euonymus and ivy.

II. LIFE HISTORY and DESCRIPTION of STAGES.

The Moth.

Description :-

The following is a description of the moth given by Adkin (1907) and which appears to be the only one which has been published in Britain :-

"Tortrix pronubana is easily recognised by the bright orange colour of its hind wings, which at once distinguishes it from all its allies that are known to occur in Britain.

The Male (Figure 2), measures from 15 - 17 mm. in expanse. Forewings warm greyish brown, faintly reticulated with darker brown, with a broad rich red brown fascia from the middle of the costa, where it is narrowest, to the inner margin, where it broadens out, extends /

extends to the anal angle and unites with an irregular triangular patch of the same colour that occupies the apical and hind marginal areas. There is also a dark shade on the inner margin between the fascia and the base of the wing. The reticulations on the darker markings have a distinct bluish colour when seen in a bright light. Hind wings bright orange, bordered with black, with a few black scales scattered along the veins. Cilia of the fore wing, brownish orange, of the hind wings pale orange.

The Female (Figure 1) is a larger and more sombre insect. It measures from 18 - 22 m.m. in expanse, is slightly paler in colour than the male and the reticulations are more clearly defined. The brown fascia is of a duller and less reddish tone and its central portion is often indicated only in outline as is also the triangular patch of the apical and hind marginal regions. The cilia of the front wings are brown from the apex for about two-thirds of their distance, where they shade into orange towards the anal angle. Those of the hind wings are orange. The orange rings of the body are more distinct than in the male. The female when at rest, might easily be passed over as a pale example of T. heparana.

There is little variation in the fore wings, beyond one individual being slightly darker or lighter than another, but the black scaling of the hind wings is /

is subject to very considerable modification, chiefly in the males. In the paler examples, the black border is represented by a slender line, just within the fringes and any further black scaling is hardly discernible. In other specimens the border is black and black scales are scattered along the veins; while in the darkest individuals, the black scaling spreads over the wing so thickly as to almost obscure the orange colour."

Habits :-

General observations on the life-history of the moth were begun in August 1921 but no detailed studies were then made. Detailed observations were, however, commenced towards the end of May, 1922, pupae being collected from the glass houses at Kew, the first moths emerging from these during the last week in May. The moths were then confined in cages containing young carnation plants. Food was provided in the form of sugar solution on a sponge and on blotting paper but the moths were never observed feeding. The duration of the life of the adult insect varies from 9 to 19 days, the sexes being approximately in equal proportion. Table I. shows the proportion of the sexes to one another and the duration of adult life.

TABLE I. /

TABLE I.

Emergence	Sex	Death	Duration of adult Life.
23.3.22	♀	3.4.22	12 days.
6.5.22	♀	19.5.22	14 "
16.5.22	♂	25.5.22	10 "
24.5.22	♀	9.6.22	16 "
25.5.22	♂	29.5.22	3 " (deformed specimens)
"	♀	5.6.22	11 "
"	♂	3.6.22	10 "
26.5.22	♀	5.6.22	10 "
27.5.22	♂	9.6.22	14 "
"	♂	"	" "
30.5.22	♀	"	10 "
21.6.22	♂	10.7.22	19 "

The moths are inactive during the day ; it was usual for a moth to remain frequently motionless in one spot all day long. In the greenhouses moths are rarely found during the day-time, unless disturbed from plants when they would fly a short distance and again settle down. In the early morning sun and towards dusk the adults become active and on summer evenings, they were found in the open, in numbers flying about along with T. unifasciana in the neighbourhood of privet hedges where they had passed their larval and pupal stages. The male is much more active than the female - its flight being erratic /

erratic and agitated ; the female rarely flies, but when it does its flight is steady and it does not dart hither and thither as the male usually does. The moths do not exhibit any marked attraction to artificial light - but in the laboratory it was found that they showed a tendency to keep at the side of the cage nearest the window.

fo / Pairing :-

So far as has been observed the female pairs only once in her life time, and that very shortly after the moths have emerged. In one case a newly emerged male was put into a cage containing several females. It flew excitedly round the cage and paired immediately with one of the females. In this instance pairing lasted $1\frac{1}{2}$ hours.

fo / Egg-Laying :-

The female commences egg-laying almost immediately the act of pairing has been completed. In the laboratory eggs were laid occasionally during the day but much more frequently oviposition took place overnight or in the early morning and egg masses were found in the morning which had not been present the previous evening. This confirms observations made in the open when the moths were found to be active in the early morning and in the evening. The eggs are laid in masses usually on the upper surface of the leaves /

leaves of the host plant but occasionally masses are to be found on the under surface also. This position is, however, not common. In captivity in the laboratory, females have laid two or three batches of eggs on the under side of leaves of carnations and privet - in addition to several egg masses on the upper surface.

The Egg Mass. (Fig. 3). *CS*

The egg mass consists of a number of eggs which overlap, resembling the shingles of a roof and the shape of the mass, as a whole, apparently varies according to the shape of the leaf upon which it has been deposited. In the case of the long narrow leaf of the carnation - the egg mass is correspondingly long and narrow, while on the broad leaf surface of privet the mass assumes a distinct oval form. The eggs are laid in a number of masses which vary in size, the first laid masses being the larger, consisting in some cases of as many as 200 eggs, while the last deposited consist of only 10 - 20 eggs. The duration of egg laying of a single female was found to be approximately 12 - 14 days during which 7 or 8 egg masses were laid.

It is a common occurrence to find egg masses deposited on the glass sides of breeding cages in the laboratory ; on plant stakes and on the windows of the green-houses. All fertile egg-masses laid on the leaves /

leaves of host plants in the laboratory, hatched, as also did a large proportion of those laid on glass, but, frequently, these latter did not mature.

The flat egg mass is at first light green in colour and is surrounded by a mucilaginous substance. Each egg, oval in shape, consists of a large mass of yolk surrounded by an outer wall which presents a regular reticulate appearance. The "cells" of the reticulations were found, on microscopic examination, to be generally 5-sided. Towards the edges of the egg they appeared more or less elongated. No micropyle is visible.

Incubation Period (Table III. page 13)

The first egg mass was laid in the laboratory on the leaves of carnations on 27th May, 1922 and egg laying continued till the beginning of July. Conditions in the greenhouses approximated to laboratory conditions but eggs had evidently been laid there prior to the end of May. When work was begun in May 1922, larvae were present in the greenhouses of a size which seemed to indicate that eggs had been laid in April. This was confirmed in Spring 1923 when it was observed that the first moths of the year commenced to emerge in the glass-houses from the end of March onwards.

The incubation period of the eggs varies from a minimum of 12 days to a maximum of 24 days, as far as observations have shown. The average period is 16 - 17 /

17 days. In 1922, eggs laid between 27th May and 10th June all hatched within a period of 12 - 13 days. The average temperature during this period was 69.7°F . On the other hand, eggs laid between 22nd June and 2nd July had an incubation period of 18 - 19 days. This longer period is explained by a fall in temperature. The average temperature during the period fell to 62.7°F . In May 1923 the maximum incubation period obtained in the experiments (24 days) was accompanied by a still lower temperature - an average of 55.7°F over the period. It is thus clearly shown that the incubation period of the eggs depends on temperature conditions. Moisture is, in all probability, another factor governing the development of the egg-masses. The death of many of the egg-masses laid on the glass sides of the breeding cages may be explained in this way.

Development :

The development of the eggs, as seen by the naked eye and low power hand lens, shows several successive changes in colour of the egg mass. At first bright green, the mass becomes gradually darker green in colour and eventually each egg shows two small dark dots representing a pair of eyes. The egg mass thus assumes a dark green colour - dotted all over with small dark brown points. The next stage of development is the appearance of the mandibles as dark objects and the egg-mass, as a whole, becomes greyish-green in colour. Just prior to hatching,

the young larvae can be seen within the egg shells actively opening and shutting their mandibles and twitching their abdomens. The larvae, on emerging, gnaw a hole in the egg shells - push their heads through and thus rapidly escape. The first young larvae emerged in the laboratory on 8th June.

TABLE II.

The following table shows the number of egg masses laid by two single females which had been fertilised and isolated.

TABLE /

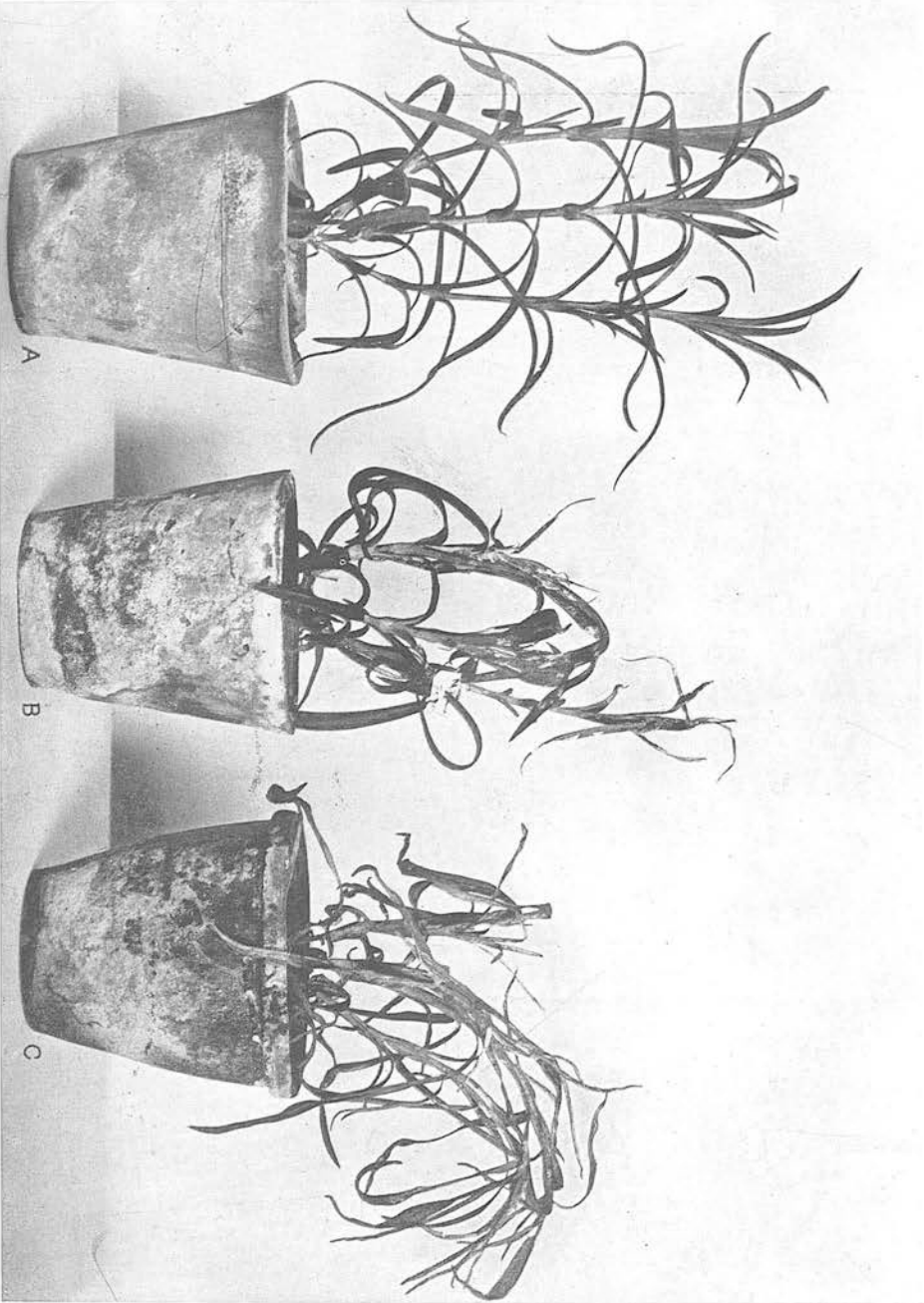


TABLE II.

Emerging	Pairing	Host	Oviposition & No. of Eggs per mass									Masses	Eggs.		
			1	2	3	4	5	6	7	8	9				
22nd June	22nd June	Carnation	22nd	23rd	25th	25th	25th	26th	28th	4th	5th	6th	9	9	-
			138	54	66	51	33	30	4	2	3	380-400			
25th June	25th June	Privet	25th	26th	27th	28th	30th	2nd	2nd	3rd	6th	9-10	20	600-700	
			180 200	100	67	74	32	90	40	20	20				

TABLE III. /

TABLE III.Tabular Statement of Incubation Period of Eggs.

Host.	Deposition.	Hatching.	Incub. Period.
Carnation	28.5.22	7-8.6.22	12 days
"	"	10.6.22	13 "
"	30.5.22	11-12.6.22	12-13 "
On glass of cage	"	12.6.22	13 "
" "	31.5.22	11-12.6.22	12 "
Carnation	22.6.22	10.7.22	18-19 "
"	25.6.22	12.7.22	18 "
"	26.6.22	13.7.22	18 "
Privet	25.6.22	13.7.22	18 "
"	28.6.22	15-16.7.22	18-19 "
"	3.7.22	21.7.22	19-20 "
"	30.4.23	20.5.23	20 "
Carnation	3.5.23	26.5.23	23-24 "
"	18.5.23	7.6.23	21 "

Av. Temp. 28th May - 12th June, 1922 = 69.6°F.

" " 22nd June - 7th July, 1922 = 62.7°F.

" " 30th April - 7th June, 1923 = 55.7°F.

The /

THE LARVA.

In the subsequent descriptions of the larval stages and duration of instars it is necessary to call attention to the fact that the observations were carried out during Spring and Summer - i.e. on the larvae of the Summer brood. The duration of the instars, therefore, cannot be taken to refer to the larvae of the Winter brood, where feeding and, consequently, growth is much slower and where the length of similar instars varies to even a greater extent than in larvae of the Summer brood.

The arrangement of the setae or hairs which are found on the bodies of many lepidopterous larvae, has been studied by Dyar (1901) and, within recent years, Fracker, (1915). In his "Classification of Lepidopterous Larvae", the latter states that "the larvae of the family Tortricidae are of sufficient economic importance to warrant the expenditure of considerable time in the study of their structure." Accordingly, it was decided that it would be of importance to study the setal arrangement of the larva of T. pronubana on the lines of Fracker's work.

It was found that the 1st stage larva alone differs in its setal arrangement from the remaining stages - the newly emerged larva lacking certain setae which appear at the first moult. Diagram A. shows the distribution of the setae on the 1st stage larva while /

while diagram B. shows the arrangement in the remaining stages (2 - 7).

Where differences occur in the external morphology of the larva at its various stages, these are noted ; otherwise, the detailed description of the full grown larva (page 25) also applies to the younger stages.

1st Stage Larva.

Length $1\frac{3}{4}$ - 2 m.m. A series of measurements of the head capsule varied from .23 - .26 m.m. in breadth. The head is dark brown to black in colour. The thoracic shield is not prominent and is slightly darker than the rest of the body, being greyish-brown in colour. The remainder of the body is pale yellowish green. The spiracles are elliptical with a dark margin. The prolegs are provided with unordinal crotchets or hooks - i.e. all are more or less of one size. The crotchets number 9 - 10 per leg and are arranged in a circle which is complete on all legs with the exception of the anal proleg where the circle is not closed.

Arrangement of Setae:

The larva is well clothed with stiff erect whiteish bristles or setae and their distribution on the thoracic and abdominal segments is diagrammatically shown in the Setal Maps (Diagrams A and B). The maps /

maps have been prepared according to Fracker's method of representing the arrangement of setae. Each segment of the larva is shown on the map by a rectangle, the upper side of which corresponds to the mid-dorsal line and the lower side to the mid-ventral line.

The distribution of the setae of the 1st stage larva of T. pronubana - which, it will be recalled, measures only 2 m.m. in length - cannot be observed without the aid of a binocular or a compound microscope. In studying this stage, in order to obtain a clear idea of the number and arrangement of the setae it was found necessary to use a compound microscope (Obj. $2/3''$) examining the larva, illuminated by artificial light and using a condensor. Studies of mounted specimens were also made.

The setae arise from slightly raised tubercles and in some cases several setae arise from the one tubercle - for example the two setae immediately beneath the spiracle on the first eight abdominal segments, both arise from the one tubercle. The tubercles are paler in colour than the surrounding epidermis, and, on microscopic examination, it is seen that they are devoid of the minute spines which are found all over the rest of the larval skin (Fig. 10). The setae are simple and arise from pits on the tubercles. They vary in length in different parts of /

of the larva, the head, carrying setae of the greatest difference in length.

Setae which are present in the first stage larva are termed by Fracker - "primary" : while those appearing at Moults I. are called "sub-primary". A comparison of the two setal diagrams A. & B shows that on the prothoracic segment, the only difference between the first and subsequent stages is the absence in the former of one seta of the group A., which is found slightly below and anterior to the prothoracic spiracle. The same difference occurs on the remaining thoracic segments (cf. A₂, A₃ - Diagram B)

The setae on the abdominal segments are numbered after Dyar (1901). Seta V. (Diagram B) is not found on any segment in the 1st stage larva ; it arises at Moults I. and is thus sub-primary. On segment 9 - groups IV. and VI. have each one seta less in the 1st stage larva. The arrangement on Segment 10 (diagram B) is similar in all stages.

Habits and Duration of Instar:

On emerging, the young larvae are extremely active and immediately wander rapidly over the food plant. They are markedly positively phototropic, always crawling towards the light. Never at any other stage in its development was the caterpillar so active - crawling rapidly about and, if in the least /

least disturbed, dropping at once suspended by a long silken thread. In the laboratory the larvae were found to congregate at the tips of the leaves of the carnation plants, hanging in festoons on their threads and spinning quickly up and down. Adkin (1908) states that the newly emerged larvae wander long distances from their birth place before settling down to feed. Observations at Kew confirmed this, to a certain extent, but there was little difficulty in getting the young larvae to settle on the plants on which they were born. In the green-houses, on the other hand, it was quite evident that larvae wandered from plant to plant and were thus rapidly scattered, although all derived from one particular egg mass. This wandering habit of the 1st stage larva undoubtedly, as Adkin has pointed out, gives the young caterpillar every opportunity of obtaining a plentiful food supply.

At this stage the larvae settle on the upper surface, (occasionally on the lower surface), of the tips of leaves, in the leaf-axils and in the flowers of carnations - either singly or two or three together. After settling, a shelter of silk is soon spun and the caterpillar commences feeding upon the upper epidermis of the leaf. On other hosts - for example on those, the leaves of which have a broad surface /

surface, it was a common occurrence to find two leaves spun together, the upper surface of one to the lower surface of the other and, between the leaf surfaces two or three larvae feeding on the epidermis. Where larvae settle in flowers - e.g. Carnation - the petals are spun together and perforated with several holes produced by the feeding of the caterpillars. Occasionally it was found that the first stage larva fed for a short time in one place and then wandered on to another. Usually, however, it remained in one spot till after the first moult.

All the larvae which emerged on 8th June and had been feeding in the laboratory on carnation plants, - moulted for the first time on 18th June. The duration of the first instar was therefore 10 - 11 days. This period was again observed in subsequent batches of larvae which were reared in the laboratory.

At Molt I. - as also at all other moults with the exception of the last, the cast skin is eaten by the newly moulted larva and only the cast head capsule is left to indicate the occurrence of a moult. This habit has been shown to be also true of the Holly Tortrix Moth, - (Eudemis naevana, Hb.) (Huie, 1917.)

2nd Stage Larva.

Length 3 - 4 m.m. Breadth of head .30-.33 m.m. This stage can readily be distinguished from the 1st stage larva by the colour of the head - which is distinctly light brown - as compared with the dark head of the previous stage. The thoracic shield is more distinct and there are now indications of dark markings appearing upon it. The colour of the body is of little value in distinguishing the stage. In general, the larva is rather more greenish in colour - as a result of feeding but it was found that, as in all other stages, the colour varied with the food plant. In some cases the larva maintains the pale yellow-green colour of the first stage but in the laboratory, where larvae were reared on carnations, they showed a more pronounced green in their coloration. The crotchets of the prolegs are uniorbital - 12 - 15 crotchets per leg.

Habits and Duration of Instar:

The habits and method of feeding of this stage are similar to those of the 1st stage larva. After the 1st moult the caterpillars continue feeding in the same position as before, spinning a slightly longer and denser covering and, as a result of their increased size, eating more rapidly, but still feeding upon the epidermis of leaves or upon the petals of the flowers.

The /

The duration of the 2nd instar was again found to be, on the whole, constant for larvae of the same brood. Larvae which moulted for the first time on 18th June - moulted again on 27th - 28th June. The duration of the 2nd instar is thus 10-11 days - the same as that of the 1st instar.

3rd Stage Larva.

Length 6 - 7 m.m. ; Breadth of head .42 - .48 m.m. The head is light brown in colour with varying darker markings, now more distinct. The thoracic shield is also light brown and has 4 dark markings towards its posterior margin. The hocks on the prolegs are uniorbital 15 - 20 (approx.) per leg.

Habits and Duration of Instar:

At the commencement of this stage the larvae continue feeding as before but towards the end of the instar and throughout the remaining instars, not only the epidermis, but the entire leaf is eaten through. As the larvae grow older and larger they feed under a more dense silken covering and are usually completely hidden from sight by the rolling of the leaf (Fig. 20) or leaves on which they are feeding. The larvae do not remain on one leaf throughout their life but, as food becomes scarce and exhausted, through the withering of attacked leaves, they move to fresh food and again spin themselves a new home and re-commence feeding. The 3rd stage larva /

feeds singly ; it was unusual to find more than one on a leaf. As the larvae grow older they become less active. Their readiness to hang down on threads when disturbed, so noticeable in the 1st stage, is not nearly so marked in the remaining instars.

The duration of the 3rd and subsequent instars varies very considerably. Owing to the habit of the larvae of feeding completely hidden between spun together leaves and, further, as a result of their wandering about on the plant, it was found extremely difficult to follow the development of individuals. The duration periods, therefore, of this and the remaining instars, are probably only approximate. Larvae of one brood (i.e. emerging from the same batch of eggs) were, however, followed throughout their development and the results obtained give approximately the length of duration of the different stages of larval growth. In rearing a batch of larvae emerging at one time, as was done, with T. pronubana, it was of interest to notice that during the first two larval stages the duration of the instars remained approximately the same for individual larvae. In the third and subsequent stages, however, some larvae grew much more slowly than others and, as a result, the duration of the instars varied to a great extent.

The duration of the 3rd instar varied from 9 to 20 days. The first 3rd stage larva moulted on July 6th - i.e. Molt III.

4th Stage Larva.

Length 8 - 10 m.m. : breadth of head .62-.67m.m.
The head is light yellow brown with various darker markings.

The thoracic shield is light brown with 4 dark patches on its posterior, border - as in the 3rd stage larva.

In the laboratory, the larvae reared on carnations had now begun to assume a more pronounced olive-green colour. The tubercles from which the setae arise are more prominent.

The crotchets of the prolegs are still unordinal and number approximately 25 - 30 per leg.

Duration of Instar:

As in the 3rd instar, there is a great variation in the duration of the 4th instar. The first 4th stage larva moulted (Moult IV.) on 18th July, and cast head capsules of 4th stage larvae were found continuously in the laboratory experiments up till the middle of August. The minimum length of the instar was 8 days and the maximum observed was 20 days.

5th Stage Larva.

Length 10-12 m.m.:breadth of head .78 - .85 m.m.
The markings on head and thoracic shield are similar to those found in the 4th stage larva.

The /

The body is more distinctly olive-green in colour with tubercles rather more prominent than heretofore.

The prolegs now are provided with two types of crotchets - some hooks being longer and others shorter. As yet, no definite arrangement of the two types is found. The 5th larval stage therefore differs from the preceding four instars, in the structure of the prolegs. The crotchets again, number, approximately, 25 - 30 per leg.

Duration of Instar :

The duration of this instar again varies. Two larvae were found on 21st July which had apparently moulted for the 5th time. Their cast head capsules were not, however, found. This phenomenon was noticed on several occasions - 6th stage - or apparently 6th stage larvae, being found but no cast heads got to confirm the occurrence of the suspected Molt.

In the laboratory Molt V was recorded from 27th July and at intervals onwards from that date.

The minimum duration of the 5th instar was 9 days - the maximum was not determined.

6th Stage Larva.

Length 12 - 15 m.m. Breadth of head .93-1.1 m.m.

Head light yellow brown with numerous dark patches as found in the 4th and 5th stage larva. Thoracic shield - yellow-green with sundry markings at its posterior margin.

The /

The dorsal surface of the body is of a darker olive green than the ventral surface - the anal segment on the dorsal surface is however, also light green in colour. The tubercles are paler than the rest of the body and the setae long and distinct.

The crotchets of the prolegs are now distinctly biordinal and are arranged so that long and short hooks alternate (fig.10). The crotchets number approximately 40 per leg.

Duration of Instar:

The first 6th stage larva moulted on 3rd August. The duration of the instar again varied but observations showed a minimum of 10 - 11 days. In two recorded instances the duration was 17 - 18 days - but it was not possible to determine the maximum period.

7th Stage Larva.

The full-grown Larva.

General Description :

The full grown larva (fig. 4) measures from 15 - 20 m.m. in length and is cylindrical in shape, tapering slightly towards both ends. The head which varies from 1.2 - 1.5 m.m. in width is of a glabrous yellow-brown colour with various dark markings, the size and position of which differ in individuals.

The /

The thoracic shield is green - rather paler than the dorsal surface of the segments of the body and is irregularly marked with dark-brown patches - most typically four, more or less triangular markings, along the posterior margin of the shield.

The dorsal surface of the mesothorax and metathorax and of abdominal segments 1 - 9, is olive green in colour, while the ventral surface, and the entire 10th segment are of a much paler green.

The spiracles are broadly elliptical in shape and have dark margins : the prothoracic and 8th abdominal spiracles are larger than the others and the 8th is slightly more dorsal in position. With the exception of the prothoracic spiracles, which are situated in the posterior half of the prothorax, all the spiracles are found towards the anterior boundary of their segments and are placed between two tubercles which bear setae. A single seta arises just dorsal to the spiracle and two, with their origin on one tubercle, just ventral and slightly anterior to it.

There are numerous folds in the body wall of the larva (fig. 4). Each segment is divided dorsally by a transverse fold towards the centre of the segment, while a longitudinal fold runs just above the legs, throughout the entire length of the larva, with the exception of the prothoracic and 10th abdominal segments.

The /

The larva is well clothed with stiff white hairs the arrangement and distribution of which is discussed below (page 32)

Detailed Description :

The Head (Figs. 5 - 8).

The head is slightly smaller and narrower than the thoracic shield and can thus be partly withdrawn beneath the shield. In a normal position the latter extends slightly over the occipital region of the head. It is not depressed and is glabrous with, as previously stated, sundry dark markings at its base.

The ocelli, which are situated on a dark patch, are 12 in number - six on each side of the head - immediately posterior to the antenna. The first five ocelli are arranged in a curve and are just visible dorsally while the sixth is more ventral in position.

The dorsal aspect of the head - including the arrangement of the hairs, is represented in figure 5.

The Antennae are 3-jointed. The basal membrane of soft chitin is well marked and gives the antenna the appearance of having 4 joints. The basal joint can be withdrawn within the basal membrane. The middle joint is larger than the other two and is dark brown in colour. It carries two bristles, one, the longer, arising ventrally, and the other, the shorter, which arises from the dorsal surface /

surface. At the anterior end of this joint there are two small cones. The terminal joint is small and also carries at its apex a fine bristle and several small cones, one of which terminates in a fine hair.

The Labrum (figs. 6 and 7) is twice as long as it is broad. The anterior margin, which projects inwards in the middle line, and divides the labrum anteriorly into two lobes, is more strongly chitinised than the remainder of the labrum. The "plate" of chitin thus formed is visible from the ventral surface. Dorsally, on each side of the middle line, the labrum carries six bristles and their arrangement agrees with that figured by Trägårdh (1917) for the labrum of Laspeyresia strobilella. Bristles III and VI. are marginal in position ; IV. and V. are submarginal, while I. and II. are situated close to the middle line, some distance from the margin of the labrum and in line with bristle VI.

Ventrally the labrum carries no bristles but is provided with six thorn-like chitinous projections - three on each lobe, towards its anterior margin. II. is distinctly smaller than I. and III. and in this, apparently differs from Trägårdh's figure of the Laspeyresia strobilella. Further, the two chitinous plates which are also present towards the centre of the labrum of the above species, one on each side of the middle line, are in the labrum of T. pronubana, entirely /

entirely absent. The ventral aspect of the head and the mouth parts are shown in figure 8.

Mouth Parts (fig. 8).

In the ventral view the mandibles are seen lying behind the maxillae and the labium. The maxillae lie, one on each side of the labium and each is connected to it by a strong chitinous rod. Each maxilla consists of the cardo and stipes, the latter being provided with two bow-shaped chitinous plates having the appearance of joints, but which, according to Börner (1907) are merely strengthening plates of chitin. Each plate bears a bristle at its anterior border, while some distance behind the posterior plate and on the border of the cardo and stipes, two other bristles arise of slightly differing length.

The Stipes carries a two jointed maxillary palp - the terminal joint of which bears several minute papillae and hairs. Also arising from the stipes and situated between the maxillary palp and the labium - lie the fused galea and lacinia - (or what apparently corresponds to the galea and lacinia). This structure carries six chitinous projections of varying size and shape. They are as follows :-
 2 small cone-like projections, each with two joints, the second of which is the smaller ; 2 flat plate-like bristles, differing from ordinary setae in being /

being broader and flatter and not tapering gradually to a fine thread-like point ; a minute bristle-bearing papilla and an ordinary seta arising close to the maxillary palp.

The Labium lies between the two maxillae and is modified, as in other Lepidopterous larvae to form the spinneret, at the tip of which the silk glands terminate. The labium is separated on each side from the maxillae by a stout rod of chitin. At the anterior end, on each side of the spinneret, is a small labial palp, two-jointed and terminating in a fine hair. The labium carries two setae which arise slightly behind the posterior pair of bristles on the stipes.

Both in the dorsal and in the ventral aspects of the head, the mandibular condyle is visible as a small knob-like projection, situated between the mandibles and the antennae, but close to the former.

Thoracic Legs. (Fig. 9).

The thoracic legs are 5-jointed and consist of the coxa, trochanter, femur, tibia and tarsus. Viewed from behind, the arrangement of setae and chitinous plates is as follows :-

The basal third of the coxa consists of a chitinous plate at the posterior margin of which a minute bristle is situated. Two long setae arise from /

from the middle of the plate one on either side.

A fourth seta is situated immediately on the inner margin of the coxa.

The trochanter is a small joint and is provided with a chitinous plate and a clear area of articular chitin at its anterior margin. At each end of this clear area, is a minute bristle.

The femur carries two bristles : one arises towards the inner margin and the other has its origin almost on the anterior surface of the joint.

The tibia which is separated from the femur and tarsus by a clear area of soft chitin, bears four bristles or setae arising towards its anterior margin. A pit - indicating the possible origin of a fifth bristle is seen towards the outer margin of the joint.

The tarsus is darker in colour than the other joints and terminates in a claw which consists of a sharp curved hook and a smaller blunt pad-shaped piece of chitin at the base of the larger claw and on its inner surface. Two short bristles arise from the inner margin, on the anterior third of the tarsus. In addition, the tarsus bears at its anterior end two thorn-like bristles, more plate-like than those arising from other parts of the leg. One of these bristles arises from the outer margin of the joint and the other over-lies the claw, with its insertion slightly posterior to the base of the claw.

On the anterior surface of the leg - the joints are devoid of bristles, with the exception of the tibia which carries two setae towards its anterior margin and situated, one on either side of the middle line of the joint.

Prolegs (Fig. 10).

The prolegs of abdominal segments 3 to 6 are crowned with a complete circle of biordinal (alternating, longer and shorter) crotchets which number between 50 and 60 per leg. The anal prolegs do not have a complete circle - the crotchets extending only rather more than half-way round the foot. The crotchets are thickened plates of chitin which are bent at the apex in the form of a hook. For some distance [around the circlet of hooks, but on the leg itself, are numerous minute hair-bearing papillae.

A tubercle, bearing 3 setae, and which is free from any spines, is situated just above each proleg. A single seta, arising from a tubercle, which is also free from any spines, is seen beneath each proleg and close to the mid ventral line. The base of the proleg is devoid of the minute spines which cover the rest of the epidermis of the body of the larva.

Arrangement of Setae.

Attention has already been drawn (page 15) to the setal maps (Diagrams A and B) which have been prepared /

Life-history and habits of *Tortrix pomonella* Ronald C. Taylor

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prepared to illustrate diagrammatically the number and distribution of the setae in the 1st stage and subsequent stage larvae.

Adkin (1907-08) figures the dorsal view of a segment of the larva of T. pronubana showing the arrangement of the hairs. It is apparent, however, that his figure can represent the dorsal view of the first eight abdominal segments alone.

In his classification of Lepidopterous Larvae, Fracker (1915) figures a segment of the larva of Cydia pomonella as representing the family Tortricidae. While the larva of T. pronubana agrees in most points with Fracker's conception of the arrangement in the Tortricidae, certain differences and variations occur which it may be of interest to note. For example, the arrangement on the 9th abdominal segment differs considerably from that on the corresponding segment of the larva of C. pomonella. Further, in one case a variation was found in the number of setae composing Group VI. (Diagram B) on segment 8 of the abdomen. According to Fracker, the genus Tortrix, in common with several other stated genera, is characterised by this group being disetose. In one specimen of T. pronubana it was found that this group consisted of two setae on one side of the segment and of three setae on the other side. This non-symmetry was, however, only once observed. In all other respects the /

the larva of T. pronubana was found to agree with the characters given by Fracker for the genus *Tortrix*. On the 8th abdominal segment, for example, the seta which, on the first seven abdominal segments arises dorsally and slightly posterior to the spiracle, on this segment invariably is anterior to and on the same level as the spiracle. Fracker believes that this is general in the Tortricidae - except for a few rare cases.

Infra-Anal Comb.

Situated beneath the anus, which is almost dorsal in its position at the apex of the 10th abdominal segment and posterior to the anal prolegs, on the ventral surface of the last segment there is a chitinous flap which is prolonged into a number of sharp bristles. This flap or comb (figs. 11 and 12) is present in all larval stages. The number of bristles varies from six to ten - the commonest number, however, being eight. In some cases the bristles are pointed but others are bifid or have a jagged end - as though they had been broken. Examination of a number of combs never once showed one with a series of pointed bristles. It may thus be assumed that the points have been broken either accidentally in making the microscopic preparations required for examination, or have been worn down through /

through use. The bristles are arranged in a fan-like fashion according to their size. Where ten bristles are present - the additional two are minute. In a dorsal view of the last segment of the larva, the apices of the bristles of the comb can be seen projecting beyond the posterior border of the segment (fig.12.)

The flap is hinged to the ventral surface of the body-wall and is capable of moving backwards and forwards through an angle of 180° . The apices of the flap can be brought together and closed in a fan-like manner. This flap appears to correspond with the "infra-anal lobe" described by Packard (1898) who states that his attention was first called to this lobe when examining some Geometrid larvae, where it takes the form of a thick conical fleshy lobe, ending in a hard chitinous point. He suggests that its function in the Geometridae is to aid in tossing the pellets of excrement away, so as to prevent contact with the body. It would appear that the hinged flap with its numerous hard chitinous bristles which is found in the larva of T. pronubana - has a similar function. It is worthy of note that although the larva feeds beneath a silken web spinning closely together leaves or petals, its feeding ground was never found full of excrement ; yet /

yet all around the twigs of privet and carnation plants, on which the larvae were feeding, in the laboratory, the excrement was plentiful. It is thus obvious that the pellets of excrement must have been ejected with some force from the home of the larva and tossed some distance away.

An anal-comb with eight points is found in the larva of T. viridana (Sich, 1915-16). It had, however not been possible to ascertain whether such a comb is present in all members of the genus *Tortrix* or whether, indeed, it is to be found throughout the entire family, *Tortricidae*. No mention is made of its presence in the larva of the Holly Tortrix Moth, Eudemis naevana.

Colour Variation in Larvae. *Coll*

Reference has already been made to the variation in colour of the larvae which renders that character useless as a means of distinguishing the different larval stages. Observations made in the green-houses where larvae were feeding on a great variety of plants (see Appendix) showed that similar stages on the same plant varied to some extent in colour. Where a larva had been feeding on a yellow-flower - e.g. Cytisus fragrans - its colour was very pale green with a more or less marked yellowish tinge. Such larvae transferred to the leaves of *Cytisus* gradually lost their yellowish tinge and became bright /

bright olive green. Larvae on one plant in particular - Nandina domestica - were, with the exception of the 1st stage, always distinctly yellow in colour with a very slight trace of green. The larvae were feeding on the leaves of this plant in numbers : the plant was not in flower. Full-grown larvae reared on this host retained the yellow colour. A yellow dye is obtained from the wood of this, and other plants belonging to the natural order - Berberideae, an interesting fact which may be correlated with the yellow colour imparted to larvae feeding on its leaves.

Larvae reared on carnations in the laboratory were more or less of the same colour at corresponding stages but even in their case, also, there were differences in the shades.

It can be concluded that, as Poulton (1892, 1903) has shown from other Lepidoptera, the food plant has a distinct effect on the colour of the larvae feeding on it. At the same time, it was found that this effect was not the same on all individuals - larvae on the same host and at similar stages of growth, differing in colour from one another.

It was not, however, found that variations in colour of larvae resulted in marked variations of the adult moths. Pupae collected from many species of plants yielded adults differing slightly in density of coloration. In some specimens the markings on /

on the fore-wings were darker than in others. Adkin (1907) has drawn attention to considerable modification of the black scaling on the hind wings particularly in the male. It is probable that this slight variation in the adult may be correlated with the colour variation in the larva but time has not permitted of a study of this matter.

Duration of 7th Instar.

The duration of the instar, so far as has been observed, varies from a minimum of 14 days, to a maximum which was not determined. The first pupa was obtained in the laboratory on 14th August. From that date onwards pupae were obtained from larvae which emerged on 8th June. In two or three cases pupation did not take place till Spring 1923.

THE PUPA.

Pupation :

Just prior to pupation the fully grown larva completely covers itself with a sheath of silk, rather denser than that spun in the previous stages of its development. The leaves are thus tightly woven together and the pupa is invisible unless its shelter is torn apart and the mass of silk threads broken,. Pupation takes place in a rolled leaf in the axil of a leaf or between two or more leaves spun together.

Description /

Description and Chaetotaxy:

The pupa is at first brown in colour but later darkens, in most cases becoming quite black. In a few cases, however, the brown colour persists throughout the pupal period. The size varies from 9 - 12 m.m., the average being 10 m.m. As a general rule, the males are rather smaller than the females but this is not absolutely constant.

Dorsal Aspect. (Fig. 13.)

The head, prothorax, mesothorax, metathorax, wings and nine abdominal segments and the cremaster are visible in a dorsal view of the pupa. The tenth abdominal segment is not visible. The 2nd and 3rd abdominal spiracles are visible and their position as well as the arrangement of the spines and hairs on the abdominal segments are shown in figure 13. The 1st abdominal segment does not bear any spines. Segments 2 - 8 inclusive, bear two rows of backwardly directed spines, one row near the anterior border of each segment and the other towards the centre. Segment 9 typically is without spines but in one case a pupa was found with the 9th abdominal segment bearing a central row of 3 or 4 spines. (fig. 14.) The spines on all segments are extremely fine-pointed and viewed in a certain light, appear as though they terminated in fine hairs.

The /

The cremaster (fig. 14) carries four pairs of hooks, 2 pairs lateral in position, which arise from the dorsal surface of the cremaster and 2 pairs arising terminally from its ventral surface.

The dorsal surface of the pupa, bears several yellowish hairs and the arrangement and distribution of these on the abdominal segments are also shown in figure 13. The hairs arise from pits and are not borne on tubercles as was found in the larva.

Ventral Aspect. (Fig. 15.)

Abdominal segments 4 - 10 are visible from the ventral surface. The 10th segment carries the anus and is separated from the cremaster by an indistinct intersegmental line. The two pairs of terminal hooks on the cremaster arise from the ventral surface.

Numerous yellowish hairs are again found. Their arrangement is similar on segments 4 - 7 - each segment bearing two single median hairs ; two groups of three sub-lateral hairs, and two lateral hairs. The sublateral groups on segment 8, consist of two hairs only ; while segment 9, although otherwise resembling the 8th segment, appears to lack the pair of median hairs. Segment 10 is without hairs and is indistinctly separated from the cremaster.

Lateral Aspect. (Fig. 16.)

The first nine abdominal segments are easily distinguishable in alateral view of the pupa. In the male chrysalis the 10th segment is not (in this view /

view) visibly separated from the cremaster by one intersegmental line : in the female, only an indistinct division is apparent (fig. 17). Thus, in neither sex, is the posterior boundary of the 10th segment well defined.

Spiracles are visible on segments 4 - 7. The spiracles on the first three abdominal segments are hidden, beneath the pupal wings. A rudimentary spiracle is present on the 8th segment. The arrangement of the pleural hairs is best described by reference to figure 16. In the lateral view of the pupa several of the dorsal and ventral hairs are also visible. The 10th segment and the cremaster do not carry any hairs.

Pupal Sex Characters :

A knowledge of sexual differentiation in the pupae of T. pronubana has proved invaluable during biological work. The external generative organs of Lepidopterous pupae have been described by Hatcher Jackson (1890) and Poulton (1890). According to both authorities the male sex of Heterocera is distinguished by a well defined linear depression in the middle line of the ventral surface of the 9th abdominal segment. This depression is guarded by two trianguloid tubercles, placed one on each side of the middle ventral line. According to Poulton, the furrow between the tubercles is the ancient opening /

opening of the pupal vas deferens and now corresponds externally to the termination of the ducts internally.

Hatchett-Jackson summarizes the characters of all the female Heterocerous pupae he has examined by "a triangular forward extension of the sternal region of the 9th abdominal segment, invading the sternal region of the 8th together with, either (a) a linear depression on the 8th sternal region and another at the apex of the triangular extension i.e. actually on the 9th segment - or (b) a single depression close to, or in the apex of, the triangular extension and produced by a confluence of the two depressions before mentioned." He further adds that, as a result of this forward extension of the 9th abdominal segment, the intersegmental line between segments 9 and 10 is not continuous from side to side across the ventral surface. Poulton's observations confirm those of Hatchett Jackson and, at the same time, he discusses the actual segmental relationship of the two depressions referred to in (a) above. The anterior opening, according to Poulton, indicates the opening of the bursa copulatrix and is always associated with the 8th abdominal sternite. The posterior opening, on the other hand, which is for the oviducts, varies in its position and is often obscure and unrecognisable and is frequently fused with the anterior aperture. Poulton states that it may occur immediately anterior to the apex of the triangular /

triangular projection of the 10th segment - i.e. on the 9th sternite, or on the projection itself and so on the 10th sternite.

Examination of pupae of T. pronubana has shown that as regards pupal sex characters, the species agrees in general with those given by Poulton and Jackson and which are summarized above. The following notes on T. pronubana in particular, may be of interest :-

Male (fig. 18):- On the 9th abdominal sternite there are two knob-like tubercles - lying between which, in the middle line, is a linear furrow or depression. The tubercles are easily visible by means of a hand lens. The intersegmental lines between segments 9 and 10 are continuous from side to side.

Female (fig. 19) :- The 9th segment extends forward in the form of a triangular projection, invading the 8th segment. The apex of the extension reaches, in the middle line, to the posterior boundary of segment 7. In the middle line and on the extension of the 9th segment there is a slit-like linear depression extending the whole length of the extension and provided on both sides with prominent lips. Thus, two separate generative openings are not visible in the pupa of T. pronubana : both are fused to form one long slit-like aperture. There is no pronounced forward /

forward extension of the 10th abdominal segment - as Poulton figures for several Heterocerous pupae : in other words, the posterior boundary of segment 9 is not markedly extended forwards, the 9th segment projecting forwards distinctly from its anterior boundary. The intersegmental lines between segments 8 and 9, and again between segments 9 and 10, are not continuous across the ventral surface of the pupa.

80 Emergence :

Prior to the emergence of the moth, the pupa wriggles itself out of its shelter by violently agitating its abdomen. In the pupa of T. prouhana abdominal segments 4, 5, 6 and 7 are moveable in the male and 4, 5 and 6 in the female. According to Chapman (1893) this grouping of moveable abdominal segments is found throughout the family Tortricidae. It is by the agitation of those segments and with the assistance of the backwardly directed spines on its dorsal surface, that the pupa moves from its pupal shelter, remaining attached by the hooks on the cremaster, to the silk which formerly had entirely surrounded it. The head and thoracic regions then split and the moth emerges, leaving the empty pupal case projecting from the leaves among which it had been protected. The moth, on first emerging, remains close to the pupal case till its wings expand. Pairing takes place soon after emergence.

Duration /

Duration of Pupal Stage :

The duration of the pupal stage was found to vary to a great extent. The minimum period recorded was 11 days while the maximum was 45 days. It was found that the pupal period of larvae of the winter brood was longer than that of larvae of the summer brood. Pupae kept under similar conditions - on the same plant and in the same greenhouse and which had commenced the pupal stage on the same day - opened after periods differing by as many as six days from one another. Table IV. shows the comparative duration of the pupal period of the summer and winter broods together with the variation that was observed in the case of pupae reared in Edinburgh and at Kew.

TABLE IV.

Pupation	Emergence	Duration of Pupal Period.
<u>1921 - Summer Brood.</u>		
(Kew.)		
7th September	22nd September	16 days.
9th "	19th "	11 "
14th "	30th "	17 "
28th August	9th "	13 "
<u>1922 - Winter Brood.</u>		
(Edinburgh).		
17th March	16th April	15 "
23rd "	6th May	45 "
30th "	16th May	38 "
<u>1923 - Winter Brood.</u>		
(Kew)		
18th April	16th May	28 "
23rd "	20th "	27 "
23rd "	18th "	23 "
25th "	17th "	22 "
8th May	7th June	30 "
16th May	11th "	26 "

Summary of Life History.

There are two main broods of T. pronubana in the year - a summer brood which emerges from eggs laid in Spring and a Winter brood which emerges from eggs laid in Autumn. During Winter (October - March) 1921 - 22, larvae, which emerged in September at Kew, were transferred to Dr R. Stewart Macdougall's laboratory, Edinburgh where the temperature corresponded to that at Kew (50° - 60°F). The larvae continued to feed slowly throughout the Winter months and showed no signs of hibernating. The first pupa was obtained from these larvae in March. The larval stage of the Winter brood was thus prolonged to 5 - 7 months. The results of the observations in Edinburgh were confirmed in the laboratory and greenhouses at Kew during Winter 1922-23. In one series of experiments where larvae were reared throughout the Winter, under greenhouse conditions the minimum period of larval life of the Winter brood was 33 weeks.

The pupal period of the Winter brood varies from $2\frac{1}{2}$ - 7 weeks (Table IV.) Moths of the Winter brood appear in April and continue to emerge throughout the Spring.

The following notes on the Summer brood are based on observations made at Kew. The first eggs of the Summer brood are laid from the middle of April onwards. In the laboratory, the minimum period of larval /

larval life of this brood was 68 days - 10 weeks - and the duration of the pupal period averaged 15 days. Moths of the Summer brood emerge from the beginning of August and onwards, when they deposit the first eggs of the Winter brood.

There is marked overlapping of broods. Larvae emerging from eggs laid late in Spring do not mature in the Autumn but feed along with young larvae of the Winter brood, derived from eggs laid in the Autumn. Further, whereas it was found that the majority of larvae emerging in the beginning of June, pupated towards the end of August, a small number, on the other hand, continued in the larval stage throughout the Winter and pupated the following Spring. It is evident, therefore that, under glass, all stages of larvae can be found throughout the year.

Mr J. H. Durrant has informed the writer that moths were seen by him near London flying around privet hedges in the open during November, which further confirms the overlapping of Summer and Winter broods.

The observations and experiments conducted at Kew confirm those made by Adkin (1907). This worker also draws attention to the prolongation of the larval life of the species and the occurrence of "two fairly well defined broods in the year." It would appear that under glass, at the temperatures at which T. pronubana is found to be troublesome at Kew (50° - 60°F.), the two annual broods are also fairly well defined /

defined - the moths issuing in numbers in early Spring and late Summer, As in the open, the larval life is prolonged during the winter months.

TABLE V.

Stage	Autumn Brood.	Summer Brood.
Egg Masses	From Middle of August	April - June.
Larvae	End of August - March, April.	Majority feed April - August - a few over-winter.
Pupae	" " March, April & May	August onwards.
Adults.	Beginning of April onwards	Majority end of August to September Others continue to emerge even into November.

The following Table (VI.) gives a summary of the observations at Kew on the larvae and moths derived from single egg masses of Summer and Winter broods respectively.

TABLE VI.

Summer /

TABLE VI.Summer Brood :Larvae reared on Carnations in laboratory.

Oviposition 27th - 28th May.

Hatching 8th - 9th June.

Pupation 1st pupa on 14th August.

Emergence 17 pupae all opened by beginning
of October.

Duration of Egg Stage = 13 days.

" " Larval " = 68 "

(" " Pupal " = 15-17 days from 1921 ob-
servations.)Minimum period egg - adult = 13 - 14 weeks.

Average temperature during period = 63°F.

Winter Brood :Larvae reared on Carnation plants in Greenhouse.

Oviposition -

Hatching 30th August.

Pupation * 1st pupa 18th April - majority be-
tween 1st and 12th May.

Emergence 1st adult 16th May.

Duration of Egg Stage = -

" " Larval " = 33 wks. (minimum) :
average 35 - 36 wks." " Pupal " = 28 days (1st pupa) -
average 27 days.Minimum period from hatching of egg to adult = 37
weeks.

Table /

* Two larvae have still not pupated on 26th June.

Table VII. gives a summary of the duration of larval instars of the Summer brood. The larvae were all derived from a single egg mass and were reared on Carnations in the laboratory, the temperature of which corresponded to that of the carnation propagating house. Owing to the habit of the larvae in the later instars of wandering about on the host plants it was found impossible to follow individuals from stage to stage : as far as possible, however, this was done. As has previously been stated (page 22) great variation occurred in the duration of the instars.

TABLE VII. /

TABLE VII.

Emerges	Dates of Moults.							Lengths of Instars in days.						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
18.6.22	27-28.	6.7.22	18.7.22	27.7.22	14.8.22									
8.6.22	6.22	7.7.22	19.7.22	* 30.7.22	* 9.8.22									
		& onwards	26.7.22	* 1.8.22	* 14.8.22									
			& onwards	& onwards	22.8.22									
								10-11	10-11	9-12	8-20	9-10	10-26	14-22
										& over	& over	& over		

Average Minimum duration of Instar = 9 - 10 days.

Average day temperature during larval life = 63.5°F.

* Denotes same larva followed throughout both instars.

III. ECONOMIC IMPORTANCE.Host Plants :

The first recorded host plant of T. pronubana in the open in Britain is a species of Euonymus (Adkin, 1905.) The species is now found in abundance in certain localities in the South of England feeding on euonymus and privet. At the Royal Botanic Gardens, Kew, it is present in large numbers, also on ivy and on laurel. It is only within the last three or four years, however, that the moth has made its appearance under glass at Kew and there the larvae are found feeding on all kinds of plants at temperatures varying between 50° and 60°F. A list of the plants on which the larva is found under glass is given in the Appendix and, although not exhaustive, it illustrates the polyphagous habit of the species and shows the wide range of plants, embracing many Natural Orders, on which the larva thrives.

Through the kindness of the Director, Mr Chittenden, a visit was paid to the Royal Horticultural Society's Gardens at Wisley in August 1922 and again in August 1923. Mr G. Fox-Wilson, the entomologist stated that he had never been troubled with T. pronubana. On both occasions a careful examination of the carnations and other plants under glass was made and it is interesting to note that no trace of pronubana was found. It is curious that an insect, which /

which has proved so troublesome at Kew, should be entirely absent from Wisley and it is probable that the species occurs in abundance only in certain localities in the South of England.

A thorough examination of the glass-houses at the Royal Botanic Gardens, Edinburgh and at the Botanic Gardens, Glasgow showed that T. pronubana did not occur in either locality.

In Edinburgh, however, it may be noted that another Tortrix species was found in large numbers on a specimen of Araukaria braziliensis in the Large Palm House. The tree was badly attacked - the larvae not only spinning the leaves together and feeding on them but also boring into the stem and shoots causing exudation of resin, defoliation and death of leaves and shoots. Numbers of larvae were collected and reared in the laboratory at Edinburgh. Moths were obtained from these in the beginning of May and were identified by Mr Durrant of the British Museum as Batodes angustiorana, Haw.

Injury to Plants by T. pronubana.

Signs of Attack.

The first indications of T. pronubana attacks are afforded by the spinning habit of the species, so characteristic of the family Tortricidae. Immediately after emerging the young larvae wander about in search of a suitable place to commence feeding and having /

having found such a place, they at once begin to spin a shelter for themselves. Where the plants attacked possess small leaves - e.g. Cytisus fragrans and Pimelea sp. - the presence of the young larvae is more noticeable than in plants possessing larger and coarser leaves - e.g. Dianthus spp. In the former case several leaves are soon spun together while in the latter type of plant the spinning of the young larvae is not easily seen since they usually spin at the tips of leaves or in leaf axils. Consequently, the characteristic knots of twisted spun-together leaves, so obvious in small leaved plants, are not at first present. As the larva grows, however, they become more apparent.

Of the various host plants cited in Appendix, Dianthus spp., Cytisus fragrans, Acacia spp. (in particular A. longifolia var. mucronata) and Chorizema ilicifolium, are the most severely attacked. In all cases, it was found that the larva feeds on the leaves and foliage, particularly at the young growing tips of the plants attacked. On carnations, the presence of young stage larvae is difficult to detect.

In addition to feeding on the leaves, it is common to find larvae attacking unopened buds. This is particularly noticeable in Carnations and Pimelea sp. A small hole (Fig. 21) in the side of the bud is the /

the only indication of infestation, the bud in all other respects appearing quite normal. Within such a bud, however, a larva is present, feeding on the flower within and thus entirely destroying it. In late Autumn, - November, the flower buds of *Pimelea* sp. were badly attacked.

The larva does not confine its feeding to leaves and unopened buds but also feeds on flowers - e.g. flowers of Carnations, *Cytisus* and *Acacias* are frequently found with larvae feeding upon them. A carnation flower attacked by 1st and 2nd stage larvae has its petals perforated with small holes resulting from the feeding of the young caterpillars.

Injury Resulting from Attacks :

The damage done to the host plants is due to the destruction of the leaf tissue and consequent reduction of leaf area. In the laboratory where young carnations were used for rearing the larvae it was found that a perfectly healthy plant (Fig. 22) was killed 6 - 8 weeks after infection with a number of larvae. The photographs (Fig. 22) show three plants, before, during, and after an attack by *T. pronubana*.

In the glass-houses at Kew, however, the larvae are not present in sufficient numbers to cause the death of the plants; if, on the other hand, they were allowed to increase in numbers, there would be a grave risk of causing the death of the smaller plants /

plants attacked. Buds and flowers are alike destroyed and thus again injury of a different nature done to the plant.

Quite apart from the damage done to the health of the host plant, the presence of pronubana larvae tends to mar its beauty - causing bunches of twisted shrivelled and withering leaves to appear (Fig. 22 & 23), and flowers to become distorted and unsightly with the petals eaten and spun together. Such harmful effects are of considerable importance anywhere, and particularly in such places as the Royal Botanic Gardens, Kew, where it is essential to maintain the beauty as well as the health of the plants.

Mode of Dispersal :

Reference has already been made (page 17) to the habit of the 1st stage larvae immediately after emerging, of wandering some distance before settling down to feed. In a greenhouse, therefore, it is obvious that infection from plant to plant at this stage is a simple matter, especially when the polyphagous habit of the larva is remembered. Further, the characteristic habit of the young larva of hanging in festoons from the leaf tips is of importance with regard to the spread of the pest from one plant to another. The slightest draught waves these festoons to and fro so that they often come in contact with neighbouring plants. In a greenhouse there is not /

not the same possibility of wind playing such a large part in the distribution of young larvae as in the open. It is frequent, however, to find quite a distinct draught in a green-house, especially on a hot summer's day when the "lights" are open.

The adult moths flying throughout the greenhouse obviously play an important part in dispersal since the females lay their eggs on practically any plant and also on the glass sides and roof of the house. It is apparent that the pest could be eradicated from any given glass house if means were taken to prevent the entrance of moths from the open. The use of insect-proof screens of wire gauze - or, less expensive, of muslin which could be fitted to cover all openings when windows are open, would effectively prevent moths entering or leaving a house. In this way, each house could be separately treated for the pest and eventually it would be entirely eradicated. The screens, however, would require to be used permanently since the species breeds freely in the open on privet, euonymus and ivy.

A further means of dispersal is found in the introduction of infected plants into houses formerly quite "clean." In Botanic Gardens it is the usual practice to transfer plants from propagating houses to the larger Green-houses. Thus it is obvious that infected plants may be conveyed from house to house and ideal conditions provided for the spread of the pest /

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Life History and Habits of Tortricid *prunivora*

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pest. This means of spread could be remedied by having all plants carefully examined before transferring them from house to house.

IV. CONTROL.

The following series of experiments were conducted with a view to ascertaining the most practical and effective methods of controlling T. pronubana, under green-house conditions. A study of the life-history has shown that such experiments should be devised to deal with the young larvae immediately after emergence.

Spraying Experiments :

A. Effect of a Nicotine Spray on Newly-Emerged Larvae.

Experiment I.

Nicotine Spray - Commercial X1 - All used in the proportion of 1 part to 30 parts water.

May 23rd. Plants sprayed ; larvae on plants
1st stage - 48 hours old :

May 25th. Plants examined - results as shown in
Table VIII.

TABLE VIII.

Plant.	Larvae Dead	Larvae alive	Totals	% killed
A (Carnation)	34	12	46	73.9
B (")	14	7	21	66.6.
C (") (control, unsprayed)	-	7 (all found)	7	-

With /

With a few exceptions the larvae not killed were in places which the spray had not reached :- i.e. protected in the axils of leaves and in several instances, sufficiently protected from the spray by a silken shelter, already partly spun.

Where the spray reached the larvae, death resulted, but it is apparent that it is not possible to reach all larvae even 48 hours after emergence.

Experiment II.:

According to Gibson & Ross (1922) - the following Nicotine and Sulphur spray was used with excellent results in greenhouses in Eastern Canada, against the Greenhouse Leaf-Tyer -

Phlyctaenia ferrugalis, H bn.

Soluble Sulphur - - - - - 1 ounce by weight
 Nicotine Sulphate (40%) - - - - 1 fluid ounce
 Water - - - - - - - - - - - - - 6 gallons.

It was decided to use this spray in the above proportions on an experimental scale, against 2nd and 3rd stage larvae of T. pronubana. The following are the results obtained :-

July 6th - 3 Carnation plants - A, B, C, on which 1st, 2nd and 3rd stage larvae were present, since emergence, all thoroughly sprayed, as above.

July 7th - Plants examined.

A.	Larvae dead	= 6	;	Larvae alive	= 36
B.	"	"	= 2	;	" " = 17
C.	"	"	= 2	;	" " = 10

Totals 10 63

% killed = 16.

In all cases the larvae killed were 1st stage and so not protected to the same extent by spun together leaves, as the older larvae. It is evident that the small percentage destroyed is due to the fact that the spray did not reach the older larvae.

B. Effect of Nicotine Sprays on Egg-Masses. 21-

Experiment III. :

Plants - carnations - each with an egg-mass on their leaves, thoroughly sprayed with X1 - All (1 in 30) : egg masses in all cases just about to hatch.

TABLE IX.

Plant	Sprayed	Larvae Emerged	Remarks
A.	25th June	-	Egg mass did not hatch : eggs shrivelled up.
B.	28th "	30th June	All eggs hatched : but 2 dead larvae found beside empty eggshells
C. Control & unsprayed		26th June	All eggs hatched.
4 isolated egg masses	30th June	1st mass hatched July 3rd	By July 9th - majority of eggs in sprayed and unsprayed masses had hatched : out of all larvae - 4 or 5 died on emerging : % dead, negligible.
4 isolated egg masses	control & unsprayed		

Experiment IV. :

Egg masses sprayed with Nicotine and Sulphur Spray (see above).

June 25th :

Mass A - of approximately 60 eggs - sprayed

" B - " " 40 "

" C - Control - and unsprayed.

June 26th :

Mass C - all eggs hatched.

June 27th :

Mass A - majority of eggs hatched - 1 dead larva beside mass.

" B " " " "

June 28th :

Mass A - All eggs hatched - except 4 which were not yet mature.

" B - 2 dead larvae beside mass - several eggs not yet hatched.

July 2nd - Remaining eggs hatched in both masses.

In the above experiments nicotine, and nicotine and sulphur sprays in the strengths used did not prevent the hatching of the egg masses. In one case only - Experiment III., Mass A. - did a sprayed egg-mass not hatch. It is likely that the death of this mass was due to some other cause - since all other masses sprayed under the same conditions hatched.

The /

The larvae, on emerging, settled down to feed, as usual, on the leaves of the plants - the nicotine by this time having apparently no effect on the young caterpillars.

In no case did the plants used in the above experiments with Nicotine sprays, suffer in the least.

C. Effect of Arsenate of Lead Spray on Larvae.

In the following experiments, Strawson - Swift Lead Arsenate Paste was used in the proportion of 6 lbs. to 50 gallons of water. This strength of spray is recommended by Lloyd (1920) for the control of Hadena oleracea.

Experiment V. :

June 6th :

Plant A. - with an egg mass of approximately 50 eggs just about to hatch - thoroughly sprayed, as above.

June 8th - egg mass found hatched.

June 9th - 8 sickly larvae found - many others wandering over plant and beginning to feed.

June 11th - 17 dead larvae : still a few feeding

June 13th - 2 " " no others visible.

Total larvae killed = 19 and plant clean.

In the control plant, all leading shoots infected with larvae from an egg mass which hatched on June 7th.

June /

June 8th :

Plant B - infected with 1st stage larvae and then sprayed as above.

" C - sprayed - eggs about to hatch.

June 9th - B - 1 dead larva.

C - egg mass just hatched.

June 11th - B - 1 dead larva.

C - 2 " "

June 13th B - 2 " "

C - 8 " "

Both plants sprayed again with freshly made spray : suspected that first spray on June 8th was not satisfactorily mixed.

June 15th B - 10 dead larvae - several living larvae feeding on under side of leaves where spray had not reached.

C - 20 " "

June 18th B - 6 " "

C - 8 " "

June 21st B - 1 " "

C - 1 " "

June 25th B - 2 " " alive - none.

C - 0 " " " 1.

Experiment closed.

Total Larvae killed B 23

" " " C 39 - 62.

Although /

Although it is not possible in this experiment to estimate the actual percentage of larvae destroyed since many wandered away from the plants, when they first emerged - yet, it is apparent that 18 days after the hatching of the egg-masses, the plants were found to be free from larvae.

The Control Plant at the end of the same period was showing signs of severe attack, the leaves being spun together and the tips of many withering, where the young larvae had been feeding.

Effect of Lead Arsenate on Plants:

Carnation plants were used in the above experiments and they did not suffer in the least from the spray : the only effect of spraying being the pale whiteish colour imparted to the leaves, by the deposit of lead arsenate left as the spray dried.

Fumigation with Hydrocyanic Acid Gas.

With a view to ascertaining whether hydrocyanic acid gas was of any value for destroying the larvae of T. pronubana a series of experiments were conducted in a small green-house (cubic contents, 828 c. ft.) specially prepared for the purpose. The following is a summary of the experiments conducted. Valuable information regarding fumigation with Hydrocyanic acid gas - and the quantities recommended were obtained from Bulletin No. 513 (Sasser and Borden, 1917) of the U.S. Department of Agriculture.

Experiment /

Experiment I. - 14th August.Strength of Cyanide used = $\frac{1}{4}$ oz. per 1000 c. ft.Exposure = $1\frac{1}{4}$ hours

Temperature during Exp. = 62°F.

Table of Results. TABLE X.

Plant	Alive - before exposure	dead - after exposure	Remarks.
Carnation	12 (3rd-7th stages)	0	Only one carnation plant showed any sign of burning of leaves.
"	7 " "	0	
"	4 " "	0	
"	3 " "	0	
"	2 " "	0	
Colecnema Albana	4 (2nd-4th stages)	0	slight burning of leaves.
Rhododendron Edgeworthii	1 (7th stage)	0	
Ihotskya ericoides	1 " "	0	
Acacia Drummondii	(3 " " 4 (1 4th "	κ 2	This plant was nearest jar containing cyanide
Acacia pulchella	5 (caricus stages	κ 1	

% of Larvae killed = 7

(κ In the light of subsequent experiments- with stronger doses of Cyanide, it is doubtful whether the death of these larvae resulted from Hydrocyanic acid gas.)

Experiment /

Experiment II. 15th August.

Plants as in Experiment I. with the surviving larvae.

Strength of Cyanide = $\frac{1}{2}$ oz. per 1000 c.ft.

Exposure = 2 hours.

Temperature = 67°F.

% of larvae killed = nil.

Experiment III. 25th August.

Plants and Larvae as in previous Experiment.

Strength of Cyanide = 1 oz. per 1000 c.ft.
(requisite quantity divided between 2 jars so as to ensure better distribution of gas)

Exposure - = $2\frac{1}{2}$ hours

% Larvae killed = Nil.

Experiment IV. : 26th August.

Plants and Larvae as before.

Strength of Cyanide = $\frac{1}{2}$ oz. per 1000 c.ft. -
but in 2 jars.

Exposure = $12\frac{1}{2}$ hours.

% Larvae killed = Nil.

During the above experiments, larvae were also placed in the greenhouse in petrie dishes covered with muslin and thus exposed to the gas. In no case, however, were larvae killed.

It may be concluded that fumigation of plants infected with larvae of T. pronubana - is of no value as a control measure.

Further /

Further Experiments :

Pyrethrum powder burnt in a large cage in which had been placed a plant attacked by larvae of T. pronubana at various stages, was found to have no effect whatever on the caterpillars.

Fumigation with Tobacco fumes as is regularly done at Kew to destroy green-fly, had also no effect on the larvae : nor were moths destroyed which had been confined in a cage - two sides of which were made of wire gauze, - the cage being placed in a greenhouse during fumigation with tobacco.

Conclusions drawn from Control Experiments :

The control of T. pronubana is a difficult problem and the brief experiments cited above are sufficient to show that it is impossible to outline complete and successful control of the insect without a further series of experiments conducted on a large scale under greenhouse conditions.

It is, however, evident, that nicotine and lead arsenate sprays are both effective if applied immediately after the larvae have emerged and before they have begun to spin up. The chief difficulty experienced was that of reaching the young larvae with the nicotine spray - while in the same way it was not easy to coat the entire plant with lead arsenate. Unavoidably - many leaf-surfaces, - (those spun together) were not covered with the poison. The older the /

the larvae the more serious was this difficulty. Both upper and lower surfaces of the leaves require to be sprayed. It is apparent that systematic and continued spraying with a nicotine spray from the time the first eggs of the year are expected to hatch - (end of March) - would account for large numbers of young larvae. Owing to the marked overlapping of broods, in this species, the spraying must be carried on at intervals - (say - once per week, plants thoroughly sprayed) throughout Spring, Summer and Autumn.

While the results of the arsenical spray are less rapid and less apparent than those of the contact insecticide - yet, since the larvae wander during feeding it is obvious that if the plants be periodically sprayed the death of many will eventually result - as has been shown in the above experiments.

Gibson and Ross (1922) found a contact spray successful for the control of Phlyctaenia ferrugalis and so it would also appear that a nicotine spray is to be recommended in the case of T. pronubana. In the experiments at Kew it was found that spraying, with any insecticide, is useless unless the young larvae (1st and 2nd stage) are tackled : the spinning habit of the species makes it impossible to reach the larvae on the leaf surfaces on which they are feeding, at later stages.

Fumigation /

Fumigation with Hydrocyanic acid gas is of no use in dealing with the pest. Molinas (1914) found that fumigation with nicotine gave no results and after experimenting with sulphuric acid and hydrocyanic acid gas - finally abandoned any type of fumigation, as successful control measures.

At Kew the larvae have been destroyed and their numbers successfully reduced by hand-picking. While this is a comparatively easy matter when the larvae are half to full grown, the younger stages are not easily seen and are thus usually passed over. Systematic destruction of larvae, pupae and egg-masses, - the latter being frequently found on the "lights" of greenhouses, - are all simple, practical means of reducing the numbers of the pest under glass. It is, however, futile to expect to eradicate entirely T. pronubana from greenhouses in a locality such as Kew, where the species is found abundantly in the open in their immediate vicinity. Mention has already been made (page 57) of the suggested use of muslin or wire-gauze screens, to fit all openings in the greenhouses and so prevent entrance and exit of adults. If this be done and systematic spraying and examination of plants be carried out before transferring from house to house, the pest would, as far as can be seen at present, be eradicated from infected greenhouses.

In /

In conclusion, it may be remarked that at Kew, T. pronubana has not proved so troublesome during 1923 - as during 1921, and 1922, when this work was first begun. Hand-picking has been carried out with success throughout the period.

V. Parasites of T. pronubana.

Millière (1859) describing the life-history of T. pronubana on the Continent, states that his observations showed the species to be parasitised to an extent of 75% - by a Tachinid - Morinia bigoti, Robineau.

Adkin (1907), working in this country, in his first observations did not obtain a single parasite. During Summer 1908, however, he reared several specimens of a Tachinid - Zenillia roseana, B and B from larvae and pupae of pronubana. The writer has recently been in communication with Adkin on this question of parasites and with his permission quotes the following extract from a letter he has received and in which Adkin records the Ichneumon - Oedematopsis scabricula, Grav : as a parasite of pronubana :-

" ----- in 1907 I turned a lot of T. pronubana eggs out on a eucynmus bush in my garden at Lewisham. In the spring of 1908 I searched the bush for larvae but could find only two and each of them had a parasitic larva attached to it. I cannot say whether there had been more of the Tortrix larvae and that they /

they had been killed by the parasites or not, but these two were eventually sucked dry by them. I sent the parasites which I reared from these two to Claude Morley and he identified them as the Ichneumon Oedematopsis scrabacula, Grav : The parasites attach themselves to their hosts externally and the best description I can give of their appearance is that they are curled between the 2nd and 3rd segments or perhaps 3rd and 4th. Larva found with parasite attached - April 12th.

Parasites emerged - May 29th and June 9th."

An Hymenopterous larva was found feeding on a larva of pronubana, just as Adkin describes above, on April 13th, 1923 on a privet hedge at Richmond. Unfortunately the parasite did not attain maturity but it is probable that this was the same species of Ichneumon as Adkin obtained.

In the observations made under glass at Kew several specimens of two (probably), Hymenopterous parasites of pronubana have been obtained - but never have any Tachinid parasites been found. In August and September 1921 - 3 Ichneumons issued from pupae of pronubana - the only parasites obtained during the summer of that year. In 1922 - no parasites were found, although a thorough search was made in the houses at Kew and 30 or 40 pupae were collected - from all of which, moths emerged. In Spring 1923 - 8 Hymenopterous cocoons were collected from plants in /

in the greenhouses ; beside each cocoon a shrivelled larvae skin was found. During April and May - the adult parasites emerged and an experiment was commenced to follow out their life-history. Owing to lack of material, however, this had, for the present, to be abandoned. The parasites obtained have been submitted to Dr Waterston of the British Museum and he has promised to identify them. At present, however, the names of the species have not yet been received. It will be interesting to see whether they are the same as those reared in the open by Adkin. Owing to the extremely small number of parasites obtained at Kew, it is quite impossible to give any figures representing the percentage of parasitism.

It would appear that, up to the present, T. pronubana is singularly free from parasites in Britain. Since the species is a native of foreign shores and is not indigenous to this country, it has evidently been introduced without the parasites, which attack it so successfully and, according to Milliere, in such numbers, in its native habitat. Hence as a natural means of control, parasitism must be regarded, at present, as of little importance - especially since parasitised larvae and, therefore, parasites, as well as unparasitised larvae are destroyed by hand-picking.

VI. Tortrix pronubana in Relation to
Dyar's Hypothesis.

Dyar (1890), in a paper on the Number of Moults of Lepidopterous Larvae, establishes an hypothesis which he has found to hold good for all the species of Lepidopterous larvae he has examined. His hypothesis states that "the widths of the head of a larva in its successive stages, follow a regular geometrical progression and if, in examining the measurements of heads taken in following out a life-history, any deviation from the calculated progression is shown it is evidence that an error has been committed or that the larva has behaved in an abnormal manner." Dyar selected the head of the larva for measurement "as the part not subject to growth during the stage, and its width as the most convenient measurement to take."

He gives, in this paper, a list of species which shows the actual and calculated larval head measurements, together with the ratio existing between the measurements of successive larval heads. The following are a few examples, to explain further Dyar's Hypothesis. All measurements are in millimeters and are correct to within .1 m.m.

Species /

Species with Five Larval Stages.Papilio cressphontes, Cram.

Calculated	.7, 1.1, 1.6, 2.3, 3.4
ratio	.66
found	.6, 1.1, 1.6, 2.2, 3.4

Datana palmii, Bent.

Calculated	.5, .9, 1.5, 2.7, 4.6.
ratio	.58
found	.5, .9, 1.6, 2.7, 4.6.

Species with Seven Larval Stages.Halisidota harrisii, Walsh.

Calculated	.4, .6, .8, 1.2, 1.7, 2.4, 3.5
ratio	.7
found	(.4, .6, .9, 1.4, 1.6, 2.3, 3.5) (.4, .6, -, 1.3, 1.7, 2.6, 3.6)

It is probable that the figures Dyar gives are averages selected from a long series of measurements to illustrate the remarkable similarity between the measurements calculated and those actually found. In the figures given in Table XI. for T. pronubana all measurements are given and it is thus apparent that whereas the general law holds, nevertheless there are considerable variations between measurements of similar stages.

The principle is of considerable importance when viewed from the point of establishing the number of moults /

moult for any given species and hints at the possibility of ascertaining the causes of variation in a life-history.

During Summer 1922, whilst conducting experimental work on the biology of T. pronubana, it was decided to investigate the larval stages and number of moults on the lines of Dyar's Hypothesis. So far as has been observed it was found that growth in the species agreed with the results which Dyar found for other Lepidopterous larvae - namely, that the widths of the head of a larva in its successive stages, follow a regular geometrical progression.

In the experiments at Kew - the procedure, was as follows :- Batches of larvae were reared on carnation plants and as the different moults occurred, the cast heads found after each moult were measured by means of an eye-piece micrometer. At the same time the breadth of the head of the newly moulted larva was also obtained and in this way a series of measurements of larval heads and cast head capsules got, from each instar. It was found impossible to follow an individual larva throughout its life because of laboratory conditions where numbers of larvae were kept together on a limited number of host plants and also since larvae, when disturbed, moved to another part of the plant so that it was not always possible to obtain for certainty the same individual that had been measured in preceding instars.

Measurements /

Measurements of larval heads were taken at the broadest part ; it was found that if cast heads were mounted in balsam on glass slides before measurement, the weight of the cover glass, caused the head to split and give too large a reading. This was especially the case in the later instars. Accordingly, it was found most satisfactory, to measure all cast head capsules without mounting, merely placing them dry, on a microscopic slide and measuring in the usual manner with the use of an eye-piece micrometer.

The breadth of larval heads of similar stages was found to vary slightly as can be seen in Table XI. given below. The variation, however, was not sufficient to upset Dyar's Hypothesis. The ratio between the breadth of larval heads of T. pronubana,^s in any two successive instars was 1.3. For example the average breadth of a 3rd stage larval head was .48 m.m. and that of a 4th stage larval head .63 m.m. The ratio - .63 : .48 - is thus 1.3. Having obtained this ratio it is possible to calculate the size of the larval head of any other instar. Further, it enables one to determine the exact stage of growth of any given larva found at random in the green-houses or elsewhere.

During 1922 - the Summer Brood larvae underwent 7 moults - the pupa appearing after the 7th moult.

In. /

In October, an interesting observation was made :-
The cast head of a recently moulted larva of the summer brood was compared with that of the larva itself and it was found that, while the cast head (.68 m.m. broad) indicated 4th stage, the head of the larva itself indicated 6th stage (1.1 m.m. broad). It is thus apparent that the 5th stage of this caterpillar had been entirely omitted and at Moults 4 instead of getting a 5th stage larva - a larva corresponding to a true 6th stage was obtained. It must be borne in mind that the duration of the first four instars of the life of this larva had extended over an unusually long period. The result of this appears to have been elimination of the usual 5th moult and the production of a 6th stage larva at moult 4. Further, similar cases of delayed development - resulting in the omission of a moult (omission of more than 1 moult was never recorded) - were observed during Autumn 1922.

The conclusion may thus be drawn that, whereas a larva may prolong its life to a considerable extent, in so doing, it undergoes fewer moults than a larva undergoing more rapid normal development. This would seem to be the direct result of the slow growth itself which would appear to render frequent moults unnecessary. It forms evidence to show, as has been frequently stated, that changes of skin or moults are the result of growth.

TABLE XI.

Head Measurements of Larvae of *T. pronubana* in Successive Instars.

Stage	Micrometer Measurements of Larval Heads. (m.m.)	Micrometer Measurements of Cast head capsules (m.m.)	Calculated Measurements m.m.
1*	<u>.23</u> , .22, .24, .24, .24	.32, .31, .31, .31	.23 = .23
2*	.31, <u>.30</u> , .33,	.41, .42, .43, .44, .44, .42	.23 x 1.3 = .30
3	<u>.51</u> , .55, .44, .46, .48, .46, .46	.46, .66*, .65*, .67*	.30 x 1.3 = .50
4	.62, .62, .62, .63, .63, .65, .67	.65, .73, .60, .60, .62, .62, .68	.50 x 1.3 = .65
5	.78 (?), .82, <u>.84</u> , .87, .88.	.80, .81, .84	.65 x 1.3 = .84
6	.94, .97, 1.0, <u>1.1</u> , <u>1.1</u> , <u>1.1</u> , 1.2	.97, .90, 1.1, 1.04, 1.1	.84 x 1.3 = 1.1
7	1.2, 1.3, <u>1.4</u> , <u>1.46</u> , 1.5, 1.5	1.46, 1.2	1.1 x 1.3 = 1.4

* denotes cast head capsules mounted in balsam before measurement - hence large readings.

Ratio calculated from Micrometer Measurements $.30/.23$ or $.63/.48 = 1.3$.

Note similarity between calculated measurements and those actually obtained by micrometer. The figures in Column 2, most closely resembling those in Column 4 are underlined.

... SUMMARY ...

The moth, Tortrix pronubana, Hb., has lately proved troublesome in the glasshouses at the Royal Botanic Gardens, Kew. Its life-history has been studied and shows two main broods in the year. The periods of duration of the various larval stages and of the pupal stage have been studied in detail.

A description of the external morphology and chaetotaxy of the larva is given. Setal maps are given showing the distribution of the setae on the thoracic and abdominal segments of the 1st. stage and full grown larvae. The chaetotaxy of the larval stages is similar, except in the 1st. stage. The growth of the larva throughout its various stages, seven in number, (normally six moults) conforms with Dyar's hypothesis that " the widths of the head of a larva in its successive stages follow a regular geometrical progression and if, in examining the measurements of heads taken in following out a life-history, any deviation from the calculated progression is shown, it is evidence that an error has been committed or that the larva has behaved in an abnormal manner."

The chaetotaxy of the abdominal segments of the pupa is described and sex characters are noted.

A series of experiments on the control of T. pronubana, under glass, shows that spraying with Nicotine or Lead Arsenate is effective if applied before and immediately after the eggs hatch. It is essential that the spray should be applied before the larvae commence to spin their webs. Destruction of the larvae by hand-picking is effective but the minute 1st. and 2nd. stage larvae are easily overlooked. Hand-picking combined with regular spraying is to be recommended as the best method of control.

Fumigation with Hydrocyanic Acid Gas was found ineffective against larvae.

The screening of windows and ventilators with gauze or muslin is recommended as a check on the infestation of clean houses.

Two Hymenopterous parasites, not yet identified, were bred from larvae and pupae of T. pronubana but

the percentage of parasitism was extremely low.

A list of host plants of T.pronubana under glass and in the open is given in an appendix.

: In conclusion, the writer wishes to express his indebtedness to Dr. J.W.Munro for his advice and encouragement during this work, which was carried out under his supervision. Thanks are due to the Director of the Royal Botanic Gardens, Kew, for the many facilities which were so willingly granted for experimental work and for general observations in the greenhouses. The writer has also to thank Mr. G. Atkinson, Artist to the Royal Gardens, Kew, for preparing the figures of the moth. : : : : :

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Trombana Hb.
R.C. Fisher

Please substitute this Table for TABLE XI in the written copy to refer. Ref.

TABLE XI

Head Measurements of Larvae of *T. trombana*, Hb. in Successive Instars.

Stage	Micrometer Measurements of Larval Heads (m.m.)	Micrometer Measurements of Cast Head-capsules (m.m.)	Calculated Measurements (m.m.)
1 st *	.22, .23, <u>.24</u> , <u>.24</u>	.31, .31, .31, .32	.24 = .24
2 nd *	<u>.24</u> , .26		
	.30, .31, <u>.33</u> , <u>.33</u>	.41, .42, .42, .43	.24 x 1.37 = .33
3 rd	<u>.33</u>	.44, .44	
	.44, <u>.46</u> , <u>.46</u> , <u>.46</u> , .48, .51, .55	.46, .58, .66, .65* .67*	.33 x 1.37 = .45
4 th	<u>.62</u> , <u>.62</u> , <u>.62</u> , .63	.60, .60, .62, .62	.45 x 1.37 = .61
	.63, .65, .67	.65, .68, .73	
5 th	.78?, <u>.82</u> , <u>.84</u> , .87	.80, .81, .84	.61 x 1.37 = .83
	.88		
6 th	.94, .97, 1.0, <u>1.1</u>	.90, .97, 1.04	.83 x 1.37 = 1.13
	<u>1.1</u> , <u>1.1</u> , 1.2	1.1, 1.1	
7 th	1.2, 1.3, 1.4, <u>1.5</u>	1.5, 1.2	1.13 x 1.37 = 1.54
	<u>1.5</u> , <u>1.5</u>		

* denotes cast head capsules mounted in balsam before measurement - hence large readings.

APPENDIX.Host Plants of Tortrix pronubana, Hb.,
under Glass at Kew.

(x denotes plants on which larvae are most abundant).

- Acacia, L. - Leguminosae.
- A. armata, R. Br.
- A. baileyana, F. Muell.
- A. cultriformis, A. Cunn.
- A. Drummondii, Benth.
- x A. longifolia, Willd.
- Var. mucronata
- A. neriifolia, A. Cunn.
- A. platyptera, Lindl.
- A. pravissima, F. Muell.
- A. pulchella, R. Br.
- A. riceana, Hernal.
- Agapetes, G. Don - Vacciniaceae
- A. Moorei.
- Albizzia, Durazz - Leguminosae.
- A. Julibrissin, Durazz
- Asparagus, Tourn. - Liliaceae
- A. sprengeri, Regel.
- Boronia, Sm. - Rutaceae.
- B. elatior, Barth.
- Bucklandia /

- Bucklandia, R. Br. - Hamamelideae.
B. populnea, R. Br.
- Callistemon, R. Br. - Myrataceae
C. Cunninghamii, Hort.
C. salignus DC.
- Calythrix, Labill. - Myrtaceae
C. tetragona, Labill.
- Cestrum, L. - Solanaceae
C. aurantiacum Lindl.
(Larvae yellowish in colour on this plant.)
- Chorizema, Labill. - Leguminosae.
^κ
C. ilicifolium, Labill.
- Clianthus, Banks & Sol. - Leguminosae.
Species not determined.
- Coleonena, Barth. & Wendl. - Rutaceae.
C. album, B. & W.
- ^κ
Coronilla, L. - Leguminosae.
C. glauca, L.
Var. *variegata*.
- Cytisus, L. - Leguminosae.
^κ
C. fragrans, Lam.
C. filipes, B. & W.
- Daphne, L. - Thymelaeaceae
D. odora, Thumb.

- * Dianthus, L. - Caryophyllaceae.
 various species.
- Erica, L. - Ericaceae.
 E. bowleana
- Ericstemon, Sm. - Rutaceae.
 E. buxifolius, Sm.
 E. scaber, Paxt.
- Geranium, L. - Geraniaceae.
 Species not determined.
- Grevillea, R. Br. - Proteaceae.
 G. alpina, Lindl.
 G. oleoides, Sieber.
 G. ornithopoda, Meissn.
 G. punicea, R. Br.
 G. robusta, A. Cunn.
 G. thelemanniana, Hugel.
- Helichrysum, L. - Compositae.
 H. rupestre, DC.
- Lhotskya, Schan - Myrtaceae.
 L. ericoides, Schan.
- Mitraria, Cav. - Gesneraceae.
 M. coccinea, Cav.
- Nandina /

- Nandina⁴, Thmb. - Berberideae.
 *
 N. domestica, Thb.
 (Larvae markedly yellow on this plant.)
- Pimelea, Banks & Sol. - Thymelaeaceae.
 P. ferruginea, Labill.
 P. Gnidia, Willd.
 var. pulchella.
 P. ligustrina, Labill.
- Poinciana, L. - Leguminosae
 P. Gilliesii, Hook.
- Psoralea, L. - Leguminosae.
 P. pinnata, L.
- Rhododendron, L. - Ericaceae.
 R. Edgeworthii, Hook.
 R. formosum, Wall.
 Var. Gibsonii.
 R. Oldhamii, Maxim.
 R. Schlippenbachii, Maxim.
- Tricuspidaria, R. & P. - Tiliaceae.
 T. lanceolata, Miq.
-

The writer is indebted to Mr J. H. Durrant for the following list of plants from which T. pronubana, Hb. has been recorded in the open, in Britain and abroad:-

- | | | |
|-------------------------|---|-------------------|
| Arbutus, L. | - | Ericaceae. |
| A. unedo L. | | |
| Aristolochia, Tourn. | - | Aristolochiaceae. |
| Species not determined. | | |
| Asphodelus, L. | - | Liliaceae. |
| A. ramosus, L. | | |
| Cneorum, L. | - | Simarubaceae. |
| C. tricoccon, L. | | |
| Cytisus, L. | - | Leguminosae. |
| C. linefolius, Lam. | | |
| Digitalis, L. | - | Scrophulariaceae |
| D. obscura, L. | | |
| Daphne, L. | - | Thymelaeaceae |
| D. gnidium, L. | | |
| Euonymus, L. | - | Celastrineae. |
| E. japonicus, L. | | |
| Euphorbia, L. | - | Euphorbiaceae. |
| Species not determined. | | |
| Geranium, L. | - | Geraniaceae. |
| Species not determined. | | |
| Jasminum, L. | - | Oleaceae. |
| Species not determined. | | |

- Ligustrum, L. - Oleaceae.
Species not determined.
- Lotus, L. - Leguminosae.
L. rectus L, & other species.
- Mercurialis, L. - Euphorbiaceae.
M. elliptica, Lam.
- Olea, L. - Oleaceae.
O. europaea, L.
- Passerina, L. - Thymelaeaceae.
Species uncertain.
- Pistacia, L. - Anacardiaceae.
P. Lentiscus L.
- Rhus, L. - Anacardiaceae.
R. Coriaria, L.
- Robinia, L. - Leguminosae.
R. pseudacacia, L.
- Rosmarinus, L, - Labiatae
R. officinalis, L.
- Rubus, L. - Rosaceae.
Species not determined.
- Scabiosa, L. - Dipsaceae.
Species not determined.
- Smilax /

- Smilax, L. - Liliaceae.
S. aspera, L.
- Solidago, L. - Compositae.
Species not determined.
- Thymus, Tourn. - Labiatae.
T. vulgaris, L.
- Viburnum, L. - Caprifoliaceae.
V. tinus L.
-