STUDIES ON THE INFLUENCE OF HOST AND INDUCED SUPERPARASITISM ON THE PUPAL PARASITE *Trichospilus pupivora* FERRIERE (EULOPHIDAE)

By

K. JAYARATHNAM, B. Sc.

THESIS

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURE (ENTOMOLOGY) OF THE UNIVERSITY OF KERALA.

DIVISION OF ENTOMOLOGY,
AGRICULTURAL COLLEGE AND RESEARCH INSTITUTE,
VELLAYANI.

1963

C E R T I F I C A T E

This is to certify that the thesis herewith submitted contains the results of bonafide research work carried out by Shri K.Jayarathnam under my supervision. No part of the work embodied in this thesis has been submitted earlier for the award of any degree.

PRINCIPAL

K.V. JOSEPH, B.A., M.Sc.,
Professor of Entomology

Agricultural College &
Research Institute,
Vellayani, Trivandrum.
Date --8--1963.

ACKNOWLEDGEMENT

I wish to express my deep sense of gratitude to Shri K.V. Joseph, B.A., M.Sc., Professor of Entomology, Agricultural College and Research Institute, Vellayani, Kerala for his guidance and valuable suggestions and also for correcting the manuscripts.

I am greatly indebted to Dr. M.R. Gopalakrishnan Nair, M.Sc., Assoc. I.A.R.I., Ph.D., F.E.S.I., Junior Professor of Entomology for his constant help and assistance rendered, in the execution of this work and preparation of thesis.

Thanks are due to Shri G. Renga Ayyer, M.Sc., Assoc. I.A.R.I., M.S. (Tennesse) for his helpful suggestions and constant encouragements.

I am greatly thankful to Dr. C.K.N. Nair, M.Sc., Ph.D. (Cornell), D.R.I.P. (Oak Ridge), Principal, Agricultural College and Research Institute, Vellayani, Kerala for kindly providing the necessary facilities.

I am grateful to Shri E.J. Thomas, M.Sc., M.S. (Iowa), Senior Lecturer in Statistics, for kindly helping me in the statistical studies in this thesis.

......

C O N T E N T S

....

I N T R O D U C T I O N

Coconut is a cash crop, cultivated in 15.87 lakhs acres in the Indian Union, yeilding 415 crores of nuts per annum, valued at Rs.54 crores. Of the total cultivated area, nearly 70% (11.75 lakhs acres) is in Kerala producing 325 crores of nuts per annum. By virtue of its great utility, and its continuous and regular supply of nuts throughout the year, the coconut palm is held in high esteem and is called the "KALPA VRIKSHA" meaning Tree of Heaven.

However, cultivation of this valuable palm in Kerala is considerably handicapped, because of the incidence of a number of insect pests some of which are very serious ones. Of these, the black-headed caterpillar *Nephantis serinopa* Meyr. (Cryptophasidae) is a very important pest taking a heavy toll of the crop especially along the coastal tracts of Kerala. Studies by Ananthanarayanan (1934), Hutson (1939), Jayaratnam (1941) and Rao et. al (1948) have shown that this pest has in association with it quite an effective parasite complex which usually keeps the pest under check. Among the various parasites which thus exert a controlling effect on this pest in the west coast areas, the Eulophid pupal parasite *Trichospilus pupivora* Ferriere, is found to be most effective. Ananthanarayanan (1934) found that *Trichospilus pupivora* could be easily reared in the Laboratory in large numbers if proper conditions of temperature and humidity were provided. It was also observed that besides the primary host namely the pupa of Nephantis serinopa, pupae of several lepidopterous insects could be used as alternate hosts for purposes of mass multiplication of the parasite.

In Kerala control of the coconut caterpillar is now brought about mainly by the mass breeding and liberation of Trichospilus pupivora in the infested coconut gardens. For this purpose the Department of Agriculture, Kerala State, has established seven parasite breeding stations at different places along the coastal tract namely Vellayani, Quilon, Kottayam, Vytilla, Trichur, Calicut and Kasargode. Besides pupae of N. serinopa, pupae of various other lepidopterous insects are being used for the mass multiplication of the parasite in these stations.

Now in the host parasite relationships, the host had been usually looked upon as a passive victim of the parasite. But Salt (1941) reviewing the information available on the effect of host upon the parasites has stated that far from being a purely passive victim which is obliterated without a trace, the host is often able to impress its mark and a very clear mark at that, upon the insect parasitoid that destroys it. He further pointed out that the characters of the parasite like behaviour, rate of reproduction, longevity and even morphological features are modified by the hosts.

From this it follows that the mass breeding of parasites using different hosts for biological control purposes, the efficiency will be governed by the host materials selected. But there exists no knowledge as to how and to what extent the different host pupae affect the characteristics of _T._ _pupivora_. Since this knowledge is of great importance and significance both from the scientific point of view and from the point of view of pest control, investigations presented in the following pages were taken up as an attempt to fill up the above mentioned lacuna in our knowledge.

In these studies a standardised strain of _T._ _pupivora_ has been maintained in the laboratory and used to parasitise different species of host pupae and the effect of these different hosts on the number of adults produced, sex ratio, duration of development, longevity and the size of the first generation of parasites, have been ascertained. Observations have also been made on the effect of different levels of superparasitism by _T._ _pupivora_ on its above mentioned characters. That the host and the different levels of superparasitism exert significant influence on these characters of the parasites is evident from these studies.

The present thesis also includes a review of literature on the effects of hosts on parasites in general and also of the work so far done on the parasite _Trichospilus_ _pupivora_ F.

REVIEW OF LITERATURE

The review of literature presented below consists of two parts. Part A deals with work done on the effect of host on parasites and Part B comprises a review of investigations carried out on the Eulophid parasite, Trichospilus pupivora F.

PART A

Although there is considerable amount of information available in literature about the host imparting to its parasite important and sometimes striking morphological, physiological and behaviouristic characters, detailed investigations done in this field are few and far between. Following is a brief review of the previous work done in this field by various workers:-

I. Effect of host on size and morphology of parasites

As early as 1844 Ratzburg pointed out that the body size of the parasite Pimpla examinator ranges from 1.67 mm. to 6 mm. depending on the size of the host on which the parasite develops. Similar findings were later recorded by Toyama (1906) working on Tachina sp.. Morril (1907) reared the Proctotrypid egg parasite, Telenomus ashmeadi on eggs of 3 species of Pentatomid bugs namely Pentatoma ligata, Euschistus servus and Thyanta custator. The average diameters of the eggs of these bugs were 1.01, 0.88 and 0.75 mm. respectively and the average head widths of the parasite emerging from these were 0.60, 0.53 and 0.45 mm. respectively. From these observations he concluded that the size of the emerged parasites has a positive correlation to the size of the host in which it develops.

Strickland (1912) found that males of the parasite Pezomachus flavocinctus (Ichneumonidae) occur in winged and wingless phases. According to him the apterous males which are much smaller than the winged forms are produced on account of insufficiency of food due to the small size of the hosts in which they develop. Similar effects were noted by other workers in subsequent years. Chewyreuv (1913) in his experiments on four species of Pimpla, (P. instigator, P. examinator, P. brassicaria and P. capulifera) supplied host pupae of different sizes to virgin female parasites for oviposition. The offsprings of virgin females were invariably males. He obtained giant males from the large pupae of Sphinx ligustri, dwarf from the small pupae of Bupalus piniarius and males of medium size from the pupae of Pieris brassicae. Thompson (1923) who reared two male progeny from one female of Pezomachus sericious, one on a large host, a cocoon of Camponotus and the other on a small host, a cocoon of Apanteles found that the males that emerged from the former were large and fully winged while those which developed from the latter were small and completely apterous. Mickel (1924) observed that the length of the Mutillid wasp Dasymutella bioculata varies from 1.5 mm. to 6 mm. depending on the size of its hosts. He plotted the length of a large number of individuals and showed that they form a bimodal curve. He also found that this species parasitizes two different genera of Bembesid wasps namely Microbembex monodonta which ranges in length from 8 to 14 mm.

and Bembex pruninosa which varies in length from 16 to 19 mm. By rearing the Mutillid on each of these hosts he showed that smaller individuals develop at the expense of the former hosts while the larger ones develop on the latter.

Hase and Albrecht (1925) noted that the variation in the size of Trichogramma evanescens was due to the effect of large and small hosts. The range in size was found to be so great that normal copulation could not take place between large and small individuals thus creating, so to say a reproductive barrier. Flanders (1930) in his studies with Trichogramma found that adult females of the parasite that emerged from the eggs of Potato tuber moth Gnorimoschema operculella are larger and more robust than those bred on eggs of Sitotroga cerealella. The eggs of the former are larger than those of the latter. Lathrop and Newton (1933) made similar observations on the effect of host on size of the Braconid parasite Opius melleus, which was found to attack the apple maggot Rhagoletis pomonella as well as the much smaller blue berry maggot Rhogoletis mendox. The authors observed that apparently there was a tendency for this species of parasite to develop into two strains, large and small as a result of being bred on the large R. pomonella and the small R. mendox respectively. They illustrated the difference in size with the help of sketches.

Oldroyds and Ribbands (1936) found that the length of the wing of Trichogramma evanescens and the number of macro-trichia forming the rows on the wings are closely correlated with the size of the whole parasite, which in its turn is correlated with the size of host. Jackson (1937) showed that the difference in size of parasites as indicated above is the direct effect of the host and not due to the selection of large and small hosts by preexisting strains of large and small parasites. He used the Ichneumonid parasite Pimpla examinator for his experiments. A female of this reared from Abraxas grossulariata measured only 10.7 mm. in length while that which developed on Pieris brassicae was 14 mm. long, this being the largest size. The smallest female progeny was reared on Ephestia kuhniella and measured 7.1 mm. in length. The smallest male descendant also was from Ephestia and this measured only 5.6 mm. in length.

Salt (1937, 1940 and 1941) in his series of research papers under the title 'Experimental studies in insect parasitism' discussed various types of effects of host on parasites. A striking effect of the species of the host on morphology of parasite was demonstrated by Salt (1937) in the egg parasite of Sialis lutaria, viz. Trichogramma semblidis. This parasite exhibits dimorphism mainly as winged and wingless males. They also differ constantly and fundamentally in several other characters. The parasite was reared on four different kinds of hosts. Three of them were moths namely Ephestia kuhniella, Sitotroga cerealella and Barathra boassica. The fourth was the original host Sialis lutaria (Neuroptera-Sialidae). The order of the size of the four hosts used was Sitotroga > Ephestia > Sialis > Barathra. The parasites which emerged from these hosts showed corresponding variation in size. But winged males that emerged from Sitotroga and Ephestia were smaller, while those from Barathra were larger than the apterous males that emerged from Sialis. It was clear that in this case it is not the amount of food that matters but difference in the kind of food provided by the different species of hosts. It was also pointed out that the dimorphism of the hymenopterous parasite appeared to be controlled by the species of the host on which it develops.

In the case of the egg parasite Trichogramma evanescens, Salt (1940) showed that the progeny of individual parasites vary in size according to the size of the species of hosts on which they are reared. Four species of hosts viz. Sitotroga, Ephestia, Agrotis (in which more than one parasite developed) and Agrotis (one parasite developed) were used in the experiment. The average length and diameter of the eggs of these were 0.44, 0.57, 0.56, 0.56 mm. and 0.23, 0.36, 0.65, 0.65 mm. respectively. Examining the length and the width of thorax, head, and abdomen of emerging parasites he found that there was an overall correlation between the size of the host egg and the size of the emerging parasites. In a particular case the parent measured 0.40 mm. in length. Its smallest female reared from an egg of Sitotroga cerealella was 0.34 mm. long while each of its progenies reared from eggs of Ephestia kuhniella measured 0.46 mm.. Its largest offspring, a solitary female from the egg of Agrotis C-nigrum attained a length of 0.5 mm. Salt (1940) further showed that within the same host species the size of the parasite is influenced by varying size of the individual hosts. In an experiment which was repeated several times, females of the egg parasite Trichogramma evanescens were allowed to oviposit in large and small sized eggs. The average length and diameter of large and small eggs were 0.59 and 0.29 and 0.48 and 0.22 mm. respectively. He compared the length of the parasites and the width of the head, thorax and abdomen of the parasites emerging from these two sizes of eggs. Parasites emerging from the small sized hosts measured on an average 0.4 mm. in length, while those emerging from larger sized eggs measured on an average 0.4 mm.. Measurements of the width of head, thorax and abdomen also showed similar differences. From these observations he concluded that in general the effect of the host on the size of the parasites is not due to the differences in the kind of food provided by various hosts but simply as one would expect to differences in its amount. He had also observed that when the amount of food is sufficient the parasite emerges. If it is just enough to allow the parasite to survive abnormal individuals called 'runts' are formed. According to him the formation of these runts is the final stage of the reduction in size of the parasites under the influence of small hosts.

II. Effect of host on oviposition and fecundity of parasites

Roubaud (1924) found that the size of the parasites which is influenced by the host in its turn influences the fecundity of the parasite. Thus he found that the chalcid *Pachycrepoideus* sp. has 27, 28 or 20 ovarioles according to its size which in turn is dependent upon its nourishment during the larval stage. Thompson and Parker (1927) in discussing the problem of host relation with special reference to entomophagous parasites have recorded that "there is marked difference in size between the adults of gregarious parasites and their hosts." They further state that it seems a general rule that the number of eggs normally deposited within a host is roughly proportional to the amount of food material available. This is dependent upon the size of the host on which it oviposits. Proper (1931) observed the fecundity of 16 females of the Chalcid Eupteromalus nidulans and found that in general the smallest individuals laid the fewest number of eggs and the largest laid the most. Salt (1935) gave some experimental data on this aspect. He observed that the solitary individuals of Trichogramma evanescens reared from the large eggs of Ephestia kuhniella laid on an average of 23.1 eggs each while the smaller females reared from smaller eggs of Sitotroga cerealella laid only 9.8 eggs.

The effect of host on the size of parasites was noted to have a direct bearing on the oviposition of parasites by Flanders (1935 a). He observed the inability of small specimens of Trichogramma evanescens to oviposit in large hosts like the eggs of Pachysphinx modesta which are readily parasitized by large ones.

Flanders (1935 b) had also observed that the host influences the fecundity of parasites which feed on the body fluids of the host. In his observations on certain parasitic hymenoptera particularly the Pteromalids, Dibrachoides, Peridesmia, Spintherus and Eutellus, he showed that when the ovarian follicles reach a certain stage of development a change occurs in the food habits of the female. In the laboratory this change was from a diet of cane sugar syrup or honey to a protein diet consisting of body fluids of host species. He noted a peculiar habit in Spintherus. It inserts its ovipositor in the host egg and secretes a material around the ovipositor. Then it carefully takes out the ovipositor so as to leave a waxy tube within the egg. It then sucks up the egg content through it.

The direct effect of the host size on the fecundity of parasites was noted by Ullyett (1936). He found that Trichogramma lutea deposits a single egg in the egg of the grain moth Sitotroga cerealella, whereas 3 or 4 eggs are laid in large eggs of Heliothis obsoleta. Taylor (1937) noted that the female of the parasite, Pleurotropis parvulus normally has six ovarioles, but small females may have only 3. Large females were found to lay 60 to 85 eggs, medium sized females 35 to 67 eggs and small females 18 to 32 eggs. He gave similar data for Dimmockia javana. Further, in his studies on the parasitic flies Zenillia libatrix, Dowden (1939) also observed a great variation in the number of ovarioles and in the number of eggs laid. According to his data the large females have about a 100 ovarioles in each ovary and they produce over 2400 eggs per female while small females may have as few as 61 ovarioles only on each side and produce only 820 eggs per female.

Experimental data for the effect of host on size of parasites and its effect on their oviposition was given by Salt (1940). He found that the large Trichogramma which emerged from the eggs of Barathra penetrate the host for oviposition more quickly than the medium sized parasites from Ephestia egg and much more quickly than small ones reared from Sitotroga eggs.

A female of *Trichogramma* was observed to take an average of 66 minutes, to find, examine, penetrate and parasitise 10 hosts, when the parasite is a small individual reared from *Sitotroga* eggs, but only 37 minutes when it is a large female reared from *Agrotis* eggs.

Narayanan and Subba Rao (1955) studying the effect of different hosts on the parasite *Microbracon gelechiae* found that the fecundity of the parasite varied when bred on different hosts. Thus the parasites bred on *Pectinophora gossypiella* laid on an average 13.22 eggs per day, those bred on *Corcyra cephalonica*, 9.75 eggs, those bred on *Scirpophaga nivella*, 10.42 eggs and those bred on *Dichocrosis punctiferalis*,3.11 eggs. Further, they observed that the parasites bred on *D. punctiferalis* laid on an average a total of only 25 eggs per female on *Dichocrosis*. In their studies, they found that in the second generation the parasite laid on an average 54 eggs per female. But in the third generation when the parasites were given *Corcyra* eggs they laid 106 eggs per female. The relatively high fecundity shown by those parasites bred on *P. gossypiella* was attributed to the high protein content of the host, which is the primary factor in the production of eggs in many insects. Narayanan (1956) in one of his series of experiments on *Trichogramma evanescens* to study the effects of nutrition on fecundity found *Corcyra* egg extract to be very necessary for stimulating the egg laying of the parasite. Lowering of fecundity was observed when the parasite was fed only with *Corcyra* egg protein without sugar. The fecundity of the parasite was highest when fed only on 10% solution of glucose, fructose, maltose or sucrose in the presence of host egg.

III. Effect of host on development of parasites

Variation in the period of development of parasites in accordance with the period of development of host in which they develop was first noted by Pantel (1910). He found that the Tachinid fly parasitoid *Compsilura concinnata* develops rapidly in the larvae of *Acronycta* and *Vanessa* in which it is full grown in some weeks and slowly in larvae of *Pieris* in which it takes several months for full development. Similarly the larvae of *Tricholyga major* (Tachinidae) was found to develop rapidly on *Vanessa* but slowly on *Macrothylacia rubi*. A correlation of life cycle of host and parasites was observed by Smith (1912). He showed that life history of *Perilampus hyalinus* is modified by the host it inhabits. He found that as a rule, the larvae in this case invariably emerge from the host at the time of pupation. If it attacks *Limnerium validum* which does not pupate until the spring the parasites remain endoparasitic and underdeveloped during winter. If it attacks *Varichaeta aldrichi* which pupates in the autumn but does not emerge until spring, the parasite becomes endoparasitic in the autumn, but develops no further until the next season. But if the parasite finds itself in a host such as two other species of *Limnerium* and two *Braconids* which not only pupate in the autumn but also proceed to immediate emergence in the same season, the parasite likewise develops quickly and emerges as full grown adult. Pierce and Holloway (1912) studying the development of the Braconid, *Chelonus texanus* a parasite of

Laphygma frugiperda observed that the time of emergence of the parasite seems to depend almost entirely upon the size of the host and that if the host feeds and grows slowly so does the parasite within.

Faure (1924) observed the influence of the host in determining whether the parasite should have one or more than one generation in an year. According to him Bracon glaphyrus normally attacks the larvae of the weevil, Baris latiocallis which is univoltine and in that host the parasite has one generation in a year. If it accidentally lays eggs in Baris chloryan which is partially bivoltine, it completes two generations in a year. This author in a subsequent paper described a similar host parasite relationship in development of Apanteles glomeratus which is a common parasite of the cabbage caterpillar Pieris brassicae. In this case the host pupates usually in the autumn and the larvae of Apanteles then becomes full grown and they spin about their host remains, the familiar cluster of cocoons in which they hibernate as pupae. If by chance the host does not pupate in autumn as often happens, the parasite hibernates as young larvae inside the host caterpillar. A similar effect is seen when it parasitizes Apriacra laegi.

Incomplete synchronism of the host parasite life cycles was observed by Marchal (1927) in his studies on the egg parasite Trichogramma cacaecia which attacks eggs of a Tortricid moth Cacaecia vasana in France. Cacaecia has only one generation in a year. The eggs of these moths enter embrionic diapause and complete their life cycle only next year. But *T. cacaecia* has two generations to each generation of its hosts. Thompson and Parker (1928) in describing the life history of the Ichneumonid parasite *Dioctes punctoria* stated that this parasite is also affected by univoltine and bivoltine strains of their hosts *Pyrausta nubilalis* and show a complete synchronism between the host Vs. parasite life cycle. Tothill et. al. (1930) observed marked variation in the length of the larval period of *Ptychomyia remota*, a Tachinid parasite of *Levuana irridescens* and it was considered that this variation is not entirely a haphazard phenomenon but an adaptation to the condition of the host.

A highly specialised phenomenon of the rate of growth of host being reflected by the parasite was described by Cox (1932). He had observed that in the eggs of the host *Ascogaster carpocapsae* the egg parasite *Chelonus annulipes* develops step by step. If the embrionic development of host is delayed, that of the parasite, is also delayed; if the host is unfertilised and therefore never hatches, the parasite similarly fails to develop. Dowden (1934) stated that the Tachinid parasite *Zenillia libatrix* does not begin to develop rapidly until its host, the gypsy moth pupates so that there is a range of two weeks or longer in the time of development. Dowden (1935) again observed the host determining the number of generation of the parasite *Brachymeria compsilurae*. This chalcid attacks both *Sturmia sentillata* which has one generation in a year and *Compsilura concinnata* which may have two or three generations. When it parasitizes the former hosts *Brachymeria* remains in the larval stage during the winter and has only one generation a year. But when it attacks the latter the parasite may have two or three generations. Webber (1937) studied the development of the Tachinid parasite of Compsilura and found that when it attacks its lepidopterous hosts late in the season all the progeny hibernate as larvae along with the host. If it attacks the same host a fortnight earlier a higher proportion of progeny develops before the host hibernates.

The development of the parasites being delayed by diapause of the host was observed by Bradley and Arbuthnot (1938) in their studies on the development of Chelonus annulepes,a Braconid parasite of corn borer. This parasite confines itself to the life cycle of its host at two separate stages. Its larva remains in its first instar when the host is about to pupate. If the host matures steadily there is no delay in the emergence of the parasite. But if the host enters a diapause the parasite remains underdeveloped until the diapause is passed. Another instance of incomplete synchronism was observed by the same authors. They found that in the field the Braconid parasite, Chelonus annulipes when it attacks the first generation egg of the multiple generation Pyrausta nubulalis does not take more than two months for complete development. But when it attacks the second generation eggs of the borer, it takes approximately 10 months for its development. When the parasitism occurs on eggs of the single generation strain of the borer the adults do not appear until approximately a full year has passed.

Salt (1940) observed the size of host influencing the developmental period of a parasite. He noticed certain variation in the developmental period of *Trichogramma evanescens*, which he suggested might perhaps be attributed to sizes of hosts in which the parasite was reared. The parasite was reared on 3 hosts under identical conditions and the time of parasitization was the same. The average developmental period in the eggs of *Ephestia* was 243 hours, in *Agrotis* 250 hours, and in *Sitotroga* 256 hours. When the percent emergence of the parasites on the three hosts were plotted against time it was apparent that the parasite from *Ephestia*, the smallest host emerged earlier than those in *Agrotis*, the slightly bigger host and much earlier than they did in *Sitrotroga* the biggest of the three. Narayanan and Subba Rao (1955) found that the developmental period of *Microbracon gelechiae* bred in different hosts varied considerably. Thus the minimum period of development was 10 days in *Corcyra cephalonia*, 11 days in *Scirpophaga nivella*, 9 days in *Pectinophora gossypiella*, 14 days in *Dichocrosis punctiferalis*, 13 days in *Galleria melonella*, 12 days in *Plusia orichalcia*, 11 days in *Chilo zonellus* and 11 days in *Gnorimoschema operculella.*

IV. Effect of host on the behaviour of parasites

Voukassovitch (1924) found an instance in which the host influenced the behaviour of its parasite in its larval stage. He observed that the larva of *Pimpla examinator* may develop either in its caterpillar host or in *Oenopthera pillerina* which lives in a webbing on or between the leaves of the Vine. If develops at the expense of a caterpillar, the full grown larva emerges from its hosts and spins a cocoon for itself beside the host remains. If however it develops in Oenopthera, its larva pupates inside the covering of the host without spinning a cocoon.

Hase (1925) showed that when females of Trichogramma evanescens were allowed to oviposit on different hosts including the ones in which they had developed, they showed no preference to any host. Salt (1934) observed Trichogramma wasting time in trying to oviposit in false hosts like fragments of glass and crystals of calcium carbonate in the presence of its original host. These observations were contrary to the host selection theory which states that if a parasite is capable of feeding on three or more host species, it tends to oviposit upon the kind in which it has developed. Taylor (1937) who observed the behaviours of Olygostra utilex the egg parasite of coconut leaf beetle Promecotheca reichei in Fiji, found that when the parasite develops in beetle egg it emerges by biting its way through the wall of the egg capsule. But when it develops on eggs of Promecotheca bicolor which have a covering of triturated leaf tissue on their upper surface, the parasite emerges by biting its way in the opposite direction ie., through the tissues of the leaf on which the host egg is laid.

Thorpe and Jones (1937) put forth proof in support of host selection principle, using the Ichneumonid, Nemeritis canescens, a larval parasite of Ephestia. This can also be reared on the small wax moth larva Meliphora grisella if it is contaminated with the smell of Ephestia . Adults reared from Ephestia attack only larvae of Ephestia in the presence of larvae of Meliphora. But adults reared from Meliphora attack Ephestia larvae alone even in the presence of Meliphora. Salt (1941) reviewing the literature on "The effect of host upon their insect parasites" stated that an instance in which the parasite actually chooses its own host species in preference to the ancestral host is yet to be described in Entomophagous forms. He gave experimental proof in support of Hase's (1925) observations. He found a pure strain of Trichogramma evanescens which was reared for 260 generations exclusively on the eggs of Sitotroga cerealella, chose the eggs of Ephestia and Agrotis for oviposition in preference to eggs of Sitotroga. Similar results were obtained by Venkataraman et.al. (1948) who found that Bracon (Microbracon) greeni after being reared on larvae of Platyedra gossypiella for 3 generations did not seem to result in an actual preference for the new host over the natural host Eublemma amabilis.

Narayanan and Subba Rao (1955) conducted olfactometer experiments to test the selective behaviour of Microbracon gelechiae bred on different hosts. In the first set of experiments, the parasite bred on Scirpophage nivella for 4 generations did not show any preference to S. nivella. But those parasites bred on Corcyra cephalonica for 7 years continuously under controlled conditions, tend to develop into a distinct race which shows preference to the newly adopted host on which it was bred even when the natural host Gnorimoshema operculella is available.

V. Effect of food plant of host on parasites

Gilmore (1938) found marked difference in the parasitisation by Apanteles congregatus on the horn worms Protoparce sexta and P. quinquemaculata fed on different varieties of tobacco. He found the parasites dying before reaching maturity when the hosts were fed on dark-fired tobacco. He attributed this mortality, to the greater nicotine content of dark-fired tobacco. Investigations of Flanders (1942) indicated that great physiological differences exist between individuals of a single host species, if such individuals feed on different food plants. These physiological differences are manifested as developmental reactions of parasites. Thus he found Habrolepis rouxit the parasite of red scale Aonidiella aurantii showing this effect clearly. When the host was on grape fruit only 3.1% of the larvae of parasite died. But when the host was on sago palm 100% of the larvae of parasites died.

Narayanan and Subba Rao (1955) observed that when grown up Plusia caterpillars collected from tobacco and gram were exposed to Microbracon gelechiae, both were parasitized. But all the grubs on tobacco caterpillar died within 3 days of feeding while those on the gram caterpillar developed normally. When very young stages of host caterpillar collected from tobacco leaves were supplied a good (9 out of 22) proportion of grubs developed normally. It is explained that the death of parasite grubs feeding on the tobacco caterpillar may be due to the toxic substance in it-nicotine. In the case of young host caterpillars, there may not be enough concentration of nicotine in them to affect the parasitic grubs when they feed on them.

VI. Effect of host on sex ratio of parasites

Attention to the fact, that the size of the individual hosts influences the sex ratio of its parasites was first called to by Chewyreuv (1913). He found that in *Pimpla instigator* which was made to parasitize pupae of different sizes a predominance of 80% males emerged from small pupae of *Pieris*, *Panolis* and *Bupalus* and a complete predominance of 100% females emerged from large pupae of *Sphinx*, *Saturnia* and *Gastropache*. When small intermediate and large pupae were furnished to female parasites, majority of parasites emerging from small and intermediate pupae were males. When the intermediate and small pupae were furnished, females predominated among the parasites emerging from the intermediate pupae and males predominated in those emerging from small pupae. He repeated and confirmed his results by conducting experiments on other 3 species of *Pimpla* namely *P. examinator*, *P. brassicae* and *P. capulifera*. These observations were further confirmed by him with information on pupae infested by parasites in the field conditions. The author collected 2000 cocoons of *Lophyrus* from the field and out of these he obtained parasites from 970 cocoons. The cocoons out of which the females emerged were twice as large as those out of which the males had emerged. Two species of parasites were obtained (1) *Exenterus* sp. of which 870 were bred out. Out of the parasites that emerged from large cocoons 21% were males and 79% females. Out of those that emerged from small cocoons 53% were males and 47% females. (2) Campoplex sp. of which 100 were bred, 30% of the parasites that emerged from large cocoons were males and 70% were females, while these were 74% and 26% respectively for small cocoons. He attributed this marked disparity in the sex ratio of Pimpla to selective oviposition by parent females which aim at providing a greater food supply for the female progeny. Holdaway and Smith (1932) got similar results in their work on Alysia manducator, a solitary parasite in the puparia of blow flies in Europe. The hosts studied were Calliphora vomitoria, Sarcophaga sp., Calliphora erythrocephala and Lucilia serricata, given in descending order of relative size. The largest puparia produced females only. The number of females increased in simple proportion to the increase in size of the puparia. This held true between different species as well as within each species. In large puparia of L. serricata the sex ratio of the parasites was 1:1.3, the males predominating, whereas from the small puparia the ratio was 1:5.1, again males predominating. Seyrig (1935) made similar observations in Madagascar on the parasites Echthromorpha hyalina and Pimpla maculiscaposa which are reared from pupae of several species of Lepidoptera. He attributed this difference in sex ratio to the infertility of small females which did not attract males so readily as did the large females and also to the small females selecting the small pupae and large females large pupae for oviposition.

Flanders (1936b) found that in certain species of Coccophagus the males can be produced only hyperparasitically whereas primary progeny from Coccid host is exclusively female. Related to this phenomenon is the fact that oviposition response of the parent female changes at the time of fertilisation. When unmated, she is attracted only to previously parasitized scales and places her egg in the body of primary parasite, whereas after mating she oviposits only in the unparasitized scales. In those groups in which this relation is not obligatory, unfertilised eggs are laid on small Coccid hosts.

Brunson (1937) studied the influence of instars of the Japanese beetle on the sex ratio of its larval parasite Tiphia popilliavora. Both second and third instar larvae were accepted for parasitization. Parasites emerging from the 2nd instar larvae were predominantly males of the ratio 1:2.8 but the parasite emerging from the 3rd instar larvae were predominantly females of the ratio 1:5.1. He transferred the eggs of parasites from the 2nd instar larvae to 3rd instar larvae. Even then preponderance of males was found. Likewise eggs transferred from 3rd instar to 2nd instar larvae "produced males and females indicating that the sex of progeny is determined at the time the egg is placed on the host." Taylor (1937) obtained similar results in the Chalcid parasite Pleurothrops parvulus. From the first instar host larvae females predominated in the ratio of 1.66:1.00 whereas in the 3rd instar larvae the preponderance of females increased to 4.34:1.00.

Clausen (1939) in his summarisation of literature on "The effect of host size upon the sex ratio of hymenopterous parasites" stated that the sex ratio of a species is in reality exceedingly variable and that it will vary (1) with the sex ratio of the host (2) with successive generation of the host (3) with different hosts (4) upon the same host and in the same season but in different geographical regions and (5) in successive years when host population is increasing or decreasing rapidly. Flanders (1946) found that Microplectron fuscipennis, parasitic on spruce saw fly and Tiphia popilliavora parasitic on Japanese beetle show preference by depositing fertilised eggs on large hosts and unfertilised eggs on small hosts. Further he found that the eggs originally laid on small hosts and transferred to bigger hosts did not show an increase in proportion of female progeny and vice versa. Another type of influence of host upon the sex ratio of parasite was found out by Rakshpal (1949) in Alophora sp. an endoparasite of the adults of Bagrada cruciferarum. He found only a single fly emerging from each host. Male parasites which have small light brown puparia developed from male hosts and female parasites which have large dark brown puparia developed from female hosts. The cause for this phenomenon is inferred to be the determination of sex due to the influence of sex hormones of the hosts. McGugan (1955) observed that the sexes of the pupal parasite of budworm Apechthis and Phaeogenes did not occur at random among male and female hosts as there was a definite tendency for female parasite to emerge from female hosts and male parasites from male hosts. This is possibly a response to host size as female budworm pupae are somewhat larger than male.

Narayanan and Subba Rao (1955) in their critical experiments found that the number of males and females of Microbracon gelechiae was nearly same when bred on Pectinophora gossypiella and Scirpophaga nivella. In the case of the parasite population developing from Corcyra cephalonica, the female predominated (73.9%). Under mass rearing conditions also similar relations were obtained between sex ratio of the parasites and the different hosts.

VII. Effect of host colouration on the pigmentation of parasite

The only recorded observation on this aspect appears to be that of Narayanan and Subba Rao (1955). Examination of the eggs of Microbracon gelechiae bred continuously for 2-3 generations in different hosts revealed that the colouration of the eggs laid changed gradually and assumed almost that of their respective hosts. Details of these observations are given in the following table.

Sl. No.	Name of the host	General colour of host	Colour of egg	No. of generations taken for the transference of the pigments
1.	Corcyra caphalonica	Pale yellow	Glistening white	--
2.	Scirpophaga nivella	Greenish yellow	Light yellow	4 generations
3.	Pectinophora gossipiella	Pinkish	Pinkish yellow	4 -do-
4.	Dichocrosis punctiferalis	Brownish with yellow and black patches	Yellowish green	2 -do-
5.	Plusia orichalcia	Green	Light green	2 -do-
6.	Agrotis ypsilon	Green	Light green	2 -do-

Further, the abdomen of the gravid female bred on the various hosts was also found to be pigmented, intensity of pigmentation depending on the colour of the host. It was also noticed that the grubs fed on S. nivella spun deep yellow silken cocoon instead of the normal glistening white cocoon. Direct transference of some pigmented material from host to the yolk of the egg during the development of the egg in the ovary was suggested as an explanation for this pigment phenomenon.

VIII. Effect of superparasitism on parasites

The occurrence of superparasitism is a matter of some importance in studying the effect of host, because some or all of the parasites feeding upon it are insufficiently nourished. This in turn alters the effect of host in its various aspects like size, vigour, behaviour, sex ratio etc. Thus Vandel (1932) stated that in the case of the parasite Mermis subnigrescens males predominate when many parasites inhabit a single host. He concluded that this was due to the effect of selective elimination of female parasites owing to the insufficiency of food. Flanders (1935) obtained a predominance of females in the ratio 2:1 in Trichogramma evanescens when three parasites developed in each egg of Estigmene lactinae. But if only a single egg was laid in a host, the progeny was found to be invariably female. Flanders (1936) found that one or more individuals of Trichogramma sp. developed in a single egg of codling moth. When a single parasite emerged from a single host its length was found to be twice that of the four small parasites that developed in one host. Further, he stated that the larger the parasites the more young ones it can produce. It was also noticed that when a parasite was superparasitized, only the size of the host determines the number of parasites developing in it. Salt (1936) found that "when a single female Trichogramma evanescens was confined on a given number of hosts, 77.6% of the progeny was females." Similar tests by increasing the number of parent females of parasites but retaining the same number of available hosts, revealed a consistent decrease in the proportion of female progeny. In an extreme case of superparasitism induced by confining 50 parent females with 100 host eggs, the percent of female progeny obtained was 43.8%. Salt (1940) studied the effect of superparasitism by Trichogramma evanescens on the eggs of Agrotis C-nigrum. He placed 50 eggs each of the host in two petridishes. In one he introduced 10 parasites and in the other 75 parasites and kept the dishes at 25°C. After 4 hours the parasites were removed and the eggs kept in separate vials. Two to 3 parasites emerged from each egg in the first and 5 or more in the second vial. Measurements showed that when the number of gregarious parasites increases the size of the individual parasite decreases. In some cases where 6 or 7 parasites emerged from a single egg, degenerate forms called 'runts' were seen. They were very inactive, short lived and in all cases died before laying eggs. Structural deformities observed are modified antennal segments and reduced wings.

Flanders (1945) postulated that increase in the proportion of males of Macrocentrus ancylivorus, a parasite of

Potato tuber moth, has correlation with superparasitism by unimpregnated females. He stated that the presence of unimpregnated females resulting from multiple mating may nullify much of the work of impregnated females if superparasitism occurs. Martin, Glen and Finney (1946) obtained data of parasites emerging from hosts superparasitized by lots of female of the parasite Macrocentrus ancylivorus which were assumed to be impregnated. It was apparant that it is the proportion of the female that increased in their progeny. Narayanan et.al. (1948) experimentally found out the effect on sex ratio of Bracon (Microbracon) gelechiae a parasite of potato tuber moth larvae in different intensities of superparasitism on the larvae of Corcyra caphalonica. They observed that when the number of parasitic grubs which share a host increases, the number of males also increases or in other words when food supply is sufficient more females are produced. They also found out that when the number of parasitic grubs that share a single host increases the developmental period also increases. Narayanan and Subba Rao (1955) studied the effect of induced superparasitism on Microbracon gelechiae. The hosts used were the final instar larvae of Corcyra. The number of grubs per host was increased from 3 to 30. In the correlation studies they obtained a highly significant negative correlation between the number of grubs per host and percentage of female and also between the number of grubs per host and percentage of development. The correlation coefficients obtained were -0.98 and -0.96 respectively which are significant at 1% level.

PART B

I. Description of the parasite

The species was described by Ferriere (1930) which for easy reference, is given below:-

Trichospilus pupivora, sp.n.

♀♂ Body orange yellow, forms sometimes with a faint violacious shine, cheeks with a brown stripe extending from eye to mouth. Antennae yellow, pedicel and funicle more or less brownish. Legs quite yellow. Abdomen brownish black, the petiolus yellow and the middle of the second segment also more or less yellowish. The ♂ has the body entirely yellow, only the end of the abdomen brown. Wings hyaline more or less smoky brown in the middle.

♀ Head quite smooth and shining. Ocelli close together. The lateral ocelli nearer to the anterior ocellus than to the eye margins. Cheeks as long as half the length of the eye. Antennae short, the scape narrow, not reaching to the front ocellus, pedicel elongate about 3 times as long as broad; the 2 ring-joints short and transverse, the 2 funicle joints subquadrate, the 1st a little longer than the second, club elongate much pointed at apex, longer than the funicle.

Thorax smooth, very finely reticulated on the mesonotum, with a few scattered long cilia. Pronotum elongated into a neck, mesonotum with strong parapsidal furrows; scutellum truncate at apex with a straight transverse furrow before the post scutellum, smooth in the middle, longitudinally densely striate on the side; post scutellum broad in the middle, rounded behind; propodeon elongate with a medien carina and small lateral spiracular furrows, spiracles small and rounded. Wings large, the hairs forming the tufts much thicker than the other discal ciliation, which begins only below the 2nd tuft; there are about 8 long hairs on the marginal vein after which the marginal ciliae are small and weak. Submarginal vein not broken; stigmal vein small with a strong club; post marginal almost absent. Legs with the hind coxae large, strongly reticulated on the outer side; hind femora only slightly broadened; the 4 tarsal joints elongate; middle tibial spur longer than the metatarsus.

Abdomen rounded broader much shorter than the thorax, smooth, very finely reticulated from the end of the 2nd segment; petiole quadrate or a little longer than broad, shorter than the hind coxae; 2nd segment the largest reaching to the middle of the abdomen, the following segments transverse. Ovipositor not visible from above.

♂ Smaller than ♀ antennae shorter scape and pedicel broader, the 1st ring joint very small, the 2nd not longer much broader, almost as broad as the funicle joints; the 2nd funicle joints quadrate, club not much longer than the pedicel, legs shorter and somewhat thicker; especially the femora, tarsi very short, the 3 first joints as long as broad.

Length: ♀ 1-1.2 mm., ♂ 0.9-1 mm.

Ananthanarayanan (1934) noted specimens measuring 1.5 to 2 mm.

II. Life history and habits

Our knowledge of life history and habits of *T. pupivora* is derived mainly from the investigationsof Ananthanarayanan (1934) at Calicut and of Jayaratnam (1941) at Peradenia in Ceylon. The review given below is based on Ananthanarayanan's studies. Any difference or additional observations made by other workers are also indicated. The mating habits were observed by both the authors. These habits as observed by them are as follows:-

The female appears normally to be fertilized while within the host pupa. Parasites that emerge in the natural way were not observed to mate. But mating was always noticed when they were let out by artificially puncturing the host pupa. In such cases the parasites were given opportunity to mate as otherwise they would not oviposit on the host pupae. It was noticed that one male fertilised a large number of females accounting for the relatively small number of males.

Oviposition:- Ananthanarayanan (1934) found that the parasite shows little or no choice as to the part of the pupa in which eggs are laid and unfertilised females do not oviposit. Jayaratnam (1941) found that when a variety of host pupae were supplied to this parasite in a tube no partiality was shown to pupae of any kind including those of the natural host.

Life history:- Eggs of the parasite are very minute, barely visible to the naked eye and appear as transparent streaks in the milky fluid content of the host pupae. The eggs are roughly oval in shape, rounded at one end and bluntly tapering at the other and measures 0.2 mm. by 0.06 mm. The eggs hatch in about 24 hours. The grubs feeding on the content of the pupa become full grown in 5-7 days after having devoured the whole contents of the host and then turn into pupa. According to Jayaratnam (1941) larval period lasts for 7 or 8 days. The full grown pupa devoid of any appendage measures 2 mm. by 0.6 mm. and is a naked pupa covered only by a very thin transparent membrane. In about 5 to 6 days after pupation the compound eyes and the 3 ocelli become bright red, the antennae are clearly marked and the abdominal ventral streak of the female is faintly visible. In about 8 to 10 days after pupation the parasites which are closely packed within the pupal case of the host become adults and emerge by biting tiny holes in the now brittle pupal cell. During hot dry weather from March to April the life cycle is completed in 15 days but during wet weather it takes upto 20 days. Jayaratnam on the other hand observed that the life cycle is completed in 16 to 23 days. He further stated that in a year, 17 to 18 generations are completed with an average period of development of 20.4 days at Peradenia, Ceylon. But at Calicut 22 generations are completed in a year with an average period of development of 16.5 days.

The adult parasite usually lives for 7 days after emergence but they live only for a shorter period in hot dry weather. Feeding them with sugar solution, yeast or dilute honey does not affect their longevity. Jayaratnam stated that in Ceylon the adult parasite lives upto 11 days in Peradenia and

7 days in Batticola and 12 days in Kurunegala.

III. Artificial breeding of the parasite

This parasite has been found eminently suitable for mass multiplication in the laboratory especially because the pupae of other lepidoptera can be used equally well as its natural host for breeding purposes. An ordinary glass specimen tube 15 cm. by 2.5 cm. with bored corks, the holes of which are closed with 90 mesh wire gauze, forms a suitable breeding cage. In each tube one or two host pupae are put and 5-10 parasites are introduced. The tiny creatures as soon as introduced settle on the pupae and begin to lay eggs in the course of 2-6 hours and die in 2-6 days after oviposition. In the course of about 6 days the attacked pupae begin to show characteristic sickly dark colour. The parasites emerge in 16 to 22 days. They are then exceedingly active and crowd towards the lighted part of the cage. In the laboratory during certain parts of the year the parasitized pupae become subject to fungal and bacterial attack. So considerable number of parasitized host pupae are destroyed. The condensation of moisture favours the growth and multiplication of these organisms. By sterilising the tubes and the corks before use the difficulties may be avoided.

IV. Influence of weather in nature and in laboratory

This parasite is highly susceptible to weather changes. They are at their best during wet weather from October to February and practically disappear from the field during the hot dry weather from March to May. In the laboratory too during hot dry weather the host pupae themselves dry up killing all the contained parasites. Further the egg laying capacity of the parasite is reduced and the few emerging parasites are small and feeble. Ramakrishna Ayyar and Ananthanarayanan (1935) experimentally found laboratory rearing was successful at a temperature of 78°F.-82°F. and relative humidity 92-94%. At high temperature such as 85°F. the development is accelerated but many of the grubs are killed because the host material gets dried up. The few specimens that emerge will be weak and undersized. On the other hand a more humid climate encourages the growth of destructive bacteria and fungi. In addition to this those that develop inside the pupae are unable to come out by puncturing the pupal skin, as it is tough. But if exposed to the sun for a short time they are able to emerge. To overcome the difficulties in breeding parasites in the dry weather, a parasite breeding box wherein temperature and humidity conditions could be suitably regulated, has been devised.

Dr. Hutson (1922) stated that in his attempts to transfer this Eulophid, which was found functioning efficiently in the North-west Province of Ceylon, to drier conditions in Batticaloa District in the Eastern Province proved unsuccessful. Ramachandra Rao et.al. (1948) stated that under the peculiar climatic conditions of the West Coast the parasite would appear to thrive best only during the prevalence of the South West monsoon, and it is fairly active during the comparatively cool and moist period between October and February and becomes considerably reduced in population during dry hot months from March to May. They further stated that on the West coast the ecological conditions needed for the species to thrive, prevail during the greater part of the year, and so the degree of parasitism rises to 75%. On the other hand in the East coast where climatic conditions are comparatively much drier, this parasite could not establish itself.

V. Potentiality of the wasp as a parasite

The average number of parasites emerging from the attacked pupae in the field was found to be 55. In the laboratory from a single pupa of Tiracola, Spodoptera and Prodenia, Jayaratnam obtained 1211, 904 and 823 parasites respectively. One parasite is capable of laying 100 to 200 eggs. A parasite attacks more than one pupa. More than one parasite attack the same pupa at a time.

Further, Jayaratnam stated that under laboratory conditions 7 to 8 days old pupae of natural host, ten days old pupae of Tiracola and 6 days old pupae of Prodenia are parasitized by this parasite.

Eventhough the parasites become rapidly reduced during hot seasons, the existing parasites or the liberated ones attack a good proportion of the then existing host pupae in the field and prevent the emergence of the moth.

By field observations it was found that (1) the parasite at its best could destroy 75% of the existing population in the pupal stage (2) live parasites are practically absent when the host pupae are also few (3) there always exist in the field some pupae inaccessible to the parasites.

VI. <u>Causes for the efficiency of the parasites</u>

According to Ananthanarayanan, the reasons for the efficiency of the parasite in the field are as follows:-
(1) It is a prolific breeder (2) A single parasite attacks more than one pupa (3) It is eminently suitable for laboratory rearing (4) It has a delicately built structure and active habits for easy and distant dispersal. (It has been recorded 3 miles away from the place of introduction.) (5) Absence of hyperparasites.

Along with some of the above mentioned causes Jayaratnam also pointed out some other causes also, ie. (1) It has a short life cycle of 16.5 days (average), whereas that of its host is 60 days (average) (2) It can parasitize host pupae of 8 days old. (3) Females outnumber males and a single male is capable of fertilising many females.

Ramachandra Rao et.al. (1950) stated that it can breed on alternative hosts in nature and is thus capable of surviving unfavourable seasons when pupae of <u>Nephantis</u> are not available.

VII. <u>Trichospilus pupivora as hyperparasite</u>

Jayaratnam (1941) found <u>T. pupivora</u> along with an Encyrtid and an Eulophid, <u>Syntomosphyrum obscuriceps</u> F. hyperparasitic on a Tachinid larval parasite of <u>Nephantis</u> <u>serinopa</u>.

Stomatomyia bezziana.

VIII. Susceptibility of *T. pupivora* to insecticides

Nirula et.al. (1958) studied the residual toxicity of field weathered insecticidal residues to *T. pupivora*. In their experiments using leaves sprayed with 0.2% DDT suspension, they found that DDT was toxic to this parasite even after 8 weeks from the date of spraying, although an exposure period of 72 hours was required to give 50% mortality. In the case of BHC however a similar low degree of toxicity reached after 5-6 days but its action was rapid until after the 2nd day on which it caused 50% mortality after an average period of exposure of 6.25 hours. Neither spray affect the immature stages of the parasites which are passed within the host. In laboratory experiments, Joseph (1959) found that DDT spray at 0.025% and above, caused 100% mortality to this parasite, 35 days after spraying.

Hosts of *T. pupivora*

Hosts attacked in nature

Ceylon

(1) *Nephantis serinopa* M. First noted by Hutson (1919) in Negombo district in Ceylon.

(2) *Thosea cervina* W.

(3) *Spodoptera mauritia* B

(4) Puparia of Tachinid parasite of *Nacolea annubilata* S.

These three hosts are recorded by Hutson from Peradenia, Lunuwala, Passara and Karunagala, quoted by Ferriere

(1930) Jayaratnam (1941) is of opinion that more evidence is necessary regarding Thosea and Spodoptera as the former was not attacked in the laboratory and the latter pupate in soil.

India

(1) Nephantis serinopa M noted in Cochin on the Malabar coast of South India in (1925), quoted by Jayaratnam (1941)

(2) Sylepta derogata F. Cotton leaf roller. Recorded by Ananthanarayanan (1939) at Calicut.

Malaya Peninsula

(1) Tirathaba rufivena W. Recorded by Corbett at Sepang, quoted by Ferriere (1930)

Java

(1) Tirattaba spp. Recorded by Paine at Buittenzorg quoted by Ferriere (1930)

Hosts attacked in the laboratory

Host pupae attacked by the parasite in the laboratory as listed by Ananthanarayanan (1939) and Jayaratnam (1941) are as follows:-

At Coimbatore (South India)

(1) Cotton semilooper - Acontia graellsii F

(2) Paddy leaf roller - Cnaphalocrosis medinalis G.

(3) A pyralid on grape vine.

(4) Castor butterfly - Ergolis merione C.

(5) A Hesperid coconut caterpillar.

(6) Cotton leaf roller - Sylepta derogata F.

(7) Paddy army worm - Spodoptera mauritia B.

(8) Tobacco cut worm - Prodenia litura F.

In the laboratory of Peradenia (Ceylon)

(1) Tiracola plagiata W.

(2) Cosmophila erosa H.

(3) Plusia spp.

(4) Terias silhetana

(5) Parnara bada W.

(6) Parnara mathias W.

(7) Borolia venella W.

(8) Homona cofferia N.

(9) Catopsila erocal C.

(10) Psara bipunctalis F.

(11) Polytella gloriosae F.

(12) Margaronia caesaly

(13) Puparia of Stomatomyia bezyiana

(14) Tachnid puparia of larval parasite of Spodoptera mauritia.

ORIGINAL INVESTIGATIONS

MATERIALS AND METHODS

A. MATERIALS

(a) Host pupae used

(1) *Phytometra* (*Plusia*) *peponis* F. (Noctuidae)

Caterpillars were collected from leaves of snakegourd in the College Farm and reared in the laboratory on snakegourd leaves. When they reached the prepupal stage they were removed and kept in petridishes. A small opening was made in the leaf fold to observe as to when they pupated. As soon as the pupae had been formed, they were removed from the cell and used for the experiments.

(2) *Prodenia litura* F. (Noctuidae)

Caterpillars were collected from banana leaves and reared in the laboratory on tender banana leaves. The caterpillars when about to pupate went into the soil provided in the cages. The soil was examined daily for pupae or prepupae, and freshly formed pupae were used for the experiments.

(3) *Orthaga exvinacea* W. (Noctuidae)

Larvae were collected from mango trees in the College Farm and reared in the laboratory on mango leaves. As soon as cocoons were formed, they were separated from the bulk breeding and kept in petridishes and as soon as they pupated they were used for the experiments.

(4) Sylepta derogata F. (Pyralidae)

The caterpillars which are leaf rollers, were collected on bhindi leaves from the field. They were bred in the laboratory on bhindi leaves. The larvae in the prepupal stage were transferred to petridishes for pupation.

(5) Lampides (Polyommatus) boeticus L. (Lycaenidae)

The caterpillars are pod borers. They were collected from the field and reared in the laboratory on pods of cowpea. The larva pupated outside the pods. As soon as the pupae were formed, they were used for the experiments.

(6) Margaronia indica S. (Pyralidae)

The caterpillars were collected from the field on leaves of bittergourd and reared in the laboratory. The full grown larvae pupated inside leaf folds. Such leaf folds were removed to petridishes and as soon as they pupated the pupae were removed for the experiments.

(7) Nephantis serinopa M. (Cryptophasidae)

Caterpillars were collected from the field and reared in the laboratory on cut pieces of coconut leaves. The larvae pupated within oval flattened cocoon of frass and silk among the galleries. These cocoons were removed carefully to petridishes. As there is only a wall of silk at the base of the cocoon the pupation could be easily observed.

(8) Gracillaria soyella D. (Gracillaridae)

The caterpillars are top shoot webbers of pulses.

They were collected from the field from *Moghania macrophylla* and were reared on *Moghania* leaves. The prepupae were removed to petridishes. When the pupae were formed they were used for the experiment.

(b) Parasites used

Parasites used for the purpose of rearing a stock culture of parasites were obtained from the Parasite Breeding Station attached to The Division of Entomology, Agricultural College and Research Institute, Vellayani.

(c) Glassware

(i) Hurricane chimneys - size 17 cm. x 11 cm.

(ii) Specimen tubes - 7.5 cm. x 1.3 cm. & 7.5 cm. x 2.5 cm.

(d) Cottonwool plugs

Cotton wool was rolled into small balls and the balls were covered with pieces of muslin cloth. The top was tied and these were used for closing tubes.

(e) Tube stand - 135 cm. x 38 cm. to hold 72 tubes

(f) Tube rack - 45 cm. x 37 cm. to hold 30 tubes

(g) Camel hair brushes

(h) Diluted sugar solution - 10% sugar solution for feeding parasites.

B. METHODS

I.

(1) Rearing stock culture of *T. pupivora*

With a view to minimise the variations in size, vigour etc. of the parasite a standard method was adopted for rearing the parasites. For this purpose, a stock culture was reared on pupae of Margaronia indica. In the method of exposing pupae to the parasites single pupae were taken in specimen tubes, (7.5 cm. x 2.5 cm.) and five parasites were introduced and kept in the tube until all the parasites died. Particular care was taken to see that the pupae used were less than 24 hours old. The parasites used were invariably those which had emerged on the same day. Only female parasites were introduced, this being possible by selecting the larger individuals in a group as the larger ones are the females.

(2) Rearing parasite on different host pupae to study the effect of host on the parasite

The first process consisted in exposing the pupae to the parasites in specimen tubes (7.5 cm. x 1.3 cm.). Five female parasites were selected from the stock culture and introduced into the tube. For selecting the females alone the following procedure was adopted. At first some parasites from the rearing tubes were allowed to crawl out under an inverted petridish placed on a sheet of white paper, under the light of a work-table lamp. One edge of the petridish was then slightly lifted for allowing a few parasites to move out on to the paper. Five larger individuals of these were guided into the exposure tube by means of a fine camel hair brush. The tube was then closed with a cotton wool plug and the parasites were examined against light with a hand lens to ensure that the five parasites introduced were all females. (When examined against light the females could be identified by observing the abdomen, which is darker in colour and has a median streak formed by the ovipositor. In the males the upper half of the abdomen is clear and the streak is absent.) (See plate 1)

The host pupa was then gently cleaned with a camel hair brush and weighed in a chemical balance individually. The pupa was then carefully introduced into the tube containing the 5 parasites. A small strip of blotting paper soaked in sugar solution was placed inside the tube to serve as food for the parasites. The tubes closed with cotton plugs were then placed on a tube rack in such a way that the bottom end pointed towards light and the pupae were at that end. (See plate 2-a) The use of narrow tubes placed in this way minimised the effort of the parasites in locating the pupae and thus ensured the efficiency of parasitism to the maximum. The pupae were thus kept exposed to the parasites till all the five parasites died. The parasitised pupae were then cleaned, removed to clean specimen tubes (7.5 cm. x 2.5 cm.) plugged with cotton wool and placed on a tube stand. (See plate 2-b) When the parasites emerged they were supplied with sugar solution on filter paper as mentioned earlier.

(3) <u>Determination of period of development</u>

The period of development is calculated as the number of days from the date of oviposition by the parasites to the date of emergence of the parasites.

(4) Determination of longevity, total number emerged and sex ratio

The number of parasites that died on each day after the day of emergence was counted. For this purpose, the live parasites in the rearing tubes were made to move to the bottom of the tube by keeping that side towards light. The cotton plug was removed, care being taken to put back into the tube any parasite present on it. The dead parasites along with the remains of the host pupa and the filter paper strip were collected in a petridish. (See plate 2-c) A fresh strip of filter paper soaked with sugar solution was supplied to parasites in the tube. The host pupal shell was broken open on the white paper and the live parasites if any were put back into the tube. All the dead parasites were grouped into small numbers of about 30 within the petridish and each group was examined under Binocular microscope, separated into males and females and counted. This was continued each day till all the parasites died. Thus in the end, data on the total number of parasites emerged and the number of the two sexes were obtained.

Longevity was determined as the average number of days lived by the parasites that emerged from a pupa. For this purpose, the number of parasites dead each day was multiplied by the number of days it has lived. The total of these products was divided by the total number of parasites emerged.

(5) Measurements of parasites

Measurements were made of 5 male and 5 female parasites selected at random from all the dead parasites emerging from a host pupa. The parasites were mounted on a slide in glycerin with dorsal side upwards. The measurements were done under a microscope with the help of micrometers. Length of male measured was that from the base of antenna to the tip of adeagus, while in females it was from the base of antenna to the tip of abdomen. Head width in both the cases was measured across the region of the eye, and width of thorax measured was between the bases of the forewings.

II. STATISTICAL STUDIES

The data obtained in the present investigations were statistically analysed using the methods of correlation, regression and analysis of covariance.

EXPERIMENTS AND OBSERVATIONS

I. Studies on the effect of different host pupae on *T. pupivora*

A series of 8 experiments were carried out in the laboratory with the purpose of ascertaining the total number of adults produced, sex ratio, developmental period, longevity and size of *T. pupivora* bred on 8 different species of host pupae. These experiments are given below.

Experiment 1

Host pupa	*Phytometra peponis* F.
Experimental details:	
Number of pupae used:	10
Age of pupae:	Less than 24 hours
Number of female parasites used for parasitising each host pupa:	5
Age of parasites used for parasitisation:	Less than 24 hours
Period during which the experiment was conducted and concluded:	21--9--1962 to 14--11--1962
Temperature during the period of experiment:	Mnm. 76° - 80° F. Mxm. 80° - 87° F.
Relative humidity during the period of experiment:	85% - 92%

Procedure - Pupae were weighed, exposed to parasites and various observations made as described on pages 43, 44 and 45. Details regarding weights of pupa used, dates of exposure and emergence of parasites are given in Table 1.

Results:- Results of the experiment are given in Appendix I, Tables 1 to 4. From table 1 it may be seen that the developmental period varies from 18 to 22 days, the average being 19.6 days. Table 2 gives the total number of adult parasites which emerged from each pupa exposed and their sex ratio. It can be observed that the number of parasites emerging from a pupa varies from 247 to 561, the average being 372.9. The ratio of male : female parasites is seen to be on an average 1:29.822. Table 3 gives the number of parasites dying on each day following their emergence and the calculated longevity. It may be noted that the parasites emerging from pupae of P. peponis live for an average period of 3.28 days. Table 4 shows the average measurements of length, width of head and width of thorax of 5 males and 5 females of the parasites emerging from each of the ten pupae of P. peponis and the calculated average measurements of the total of 50 parasites. It will be seen that the average measurements are 1.210, 0.365, 0.330 and 1.273, 0.431, 0.353 mm. respectively.

Experiment 2

Host pupa	Margaronia indica
Experimental details	
Period during which the experiment was conducted and concluded:	22--9--1962 to 21--10-1962
Temperature during the experiment:	Mnm. 76° - 80° F. Mxm. 80° - 87° F.
Relative humidity during the experiment:	85% - 91%

Details of weight of pupa and dates of exposure and emergence of parasites are given in Table 5.

Rest of the details as in Experiment 1.

Results:- Results are presented in Appendix I, Table 5 to 8. Table 5 which gives the developmental period of *T. pupivora* when bred on pupa of *M. indica* shows that the developmental period varies from 17 to 18 days, the average being 17.3 days. From table 6 it is seen that the number of parasites emerging from a pupa varies from 121 to 244, the average being 163.7 and that the ratio of male : female parasites is 1:13.699. Table 7 shows that the longevity of the parasites emerging from pupa of *M. indica* is on an average 2.298 days. Table 8 which gives the data on the average measurements of length, width of head and width of thorax of male and female parasites bred on pupa of *M. indica* shows that these measurements are 1.137, 0.343, 0.318 and 1.137, 0.379, 0.333 mm. respectively.

Experiment 3

Host pupa	*Lampides boeticus*
Experimental details	
Period during which the experiment was conducted and concluded:	24--9--1962 to 29--10-1962
Temperature during the experiment:	Mnm. 76^{0} - 80^{0} F. Mxm. 80^{0} - 87^{0} F.
Relative humidity during the experiment:	79% - 91%

Details of weight of pupa and dates of exposure and emergence of parasites are given in Table 9.

Rest of the details are as in Experiment 1.

Results:- Results are presented in Appendix I, Tables 9 to 12. Data on the developmental period of T. pupivora when bred on pupa of L. boeticus given in table 9 show that the developmental period varies from 17 to 22 days, the average being 18.5 days. It may be seen from table 10 that the number of parasites emerging from a pupa varies from 131 to 298, the average being 194.5 and that the ratio of male : female parasites on an average is 1: 15.458. From table 11 it is observed that the longevity of parasites emerging from the pupa of L. boeticus is on an average 2.292 days. From table 12 which gives the data on the average measurements of length, width of head and width of thorax of male and female parasites bred on pupa of L. boeticus it may be seen that these measurements are on an average 1.088, 0.327, 0.300 and 1.152, 0.398, 0.325 mm. respectively.

Experiment 4

Host pupa — Prodenia litura

Experimental details

Period during which the experiment was conducted and concluded:	2--10--1962 to 21-12--1962
Temperature during the experiment:	Mnm. 76° - 84° F. Mxm. 81° - 88° F.
Relative humidity during the experiment:	82% - 95%

Details of weight of pupa and dates of exposure and emergence of parasites are given in Table 13.

Rest of the details as in Experiment 1.

Results:- Results are presented in Appendix I, Tables 13 to 16.

A perusal of the data in Table 13 shows that developmental period varies from 17 to 20 days, the average being 18.5 days. Table 14 gives the number of parasites emerged and their sex ratio. It is seen that the number of parasites emerging from a pupa varies from 161 to 233, the average being 209. The ratio of male : female parasites is seen to be on an average 1:17.270. Table 15 gives the longevity of the parasites emerging from the pupa of P. *litura* and the average longevity is observed to be 4.066 days. Table 16 records the data on the measurements of length, width of head, and width of thorax of male and female parasites bred on pupa of P. *litura*. These measurements (average of 50 insects) are 1.142, 0.333, 0.302 and 1.205, 0.401, 0.322 mm. respectively.

Experiment 5

Host pupa — *Sylepta derogata*

Experimental details

Period during which the experiment was conducted and concluded:	10--10--1962 to 9---12--1962
Temperature during the experiment:	Mnm. 78° - 84° F. Mxm. 82° - 88° F.
Relative humidity during the experiment:	79% - 95%

Details regarding weight of pupa and dates of exposure and emergence of parasites are given in Table 17.

Rest of the details as in Experiment 1.

Results:- Results are presented in Appendix I, Tables 17 to 20. Table 17 gives the developmental period of T. *pupivora* when bred on pupa of S. *derogata*.

The developmental period is observed to vary from 16 to 18 days, the average being 16.9 days. Table 18 gives the total number of parasites which emerged from each pupa and their sex ratio. The number of parasites emerging from a pupa varies from 103 to 248, the average being 167.1. The ratio of male : female parasites is seen to be on an average 1:14.993. From Table 19 it may be seen that the longevity of the parasites emerging from the pupa of S. derogata is 4.963 days. Table 20 shows that the average measurements of length, width of head and width of thorax of the male and the female parasites bred on pupa of S. derogata are 1.166, 0.350, 0.323 and 1.234, 0.411, 0.333 mm. respectively.

Experiment 6

Host pupa	Orthaga exvinacéa
Experimental details	
Period during which the experiment was conducted and concluded:	16--10--1962 to 20--12--1962
Temperature during the experiment:	Mnm. 78^{o} - 84^{o} F. Mxm. 82^{o} - 86^{o} F.
Relative humidity during the experiment:	79% - 95%

Details of the weight of pupa and dates of exposure and emergence of parasites are given in Table 21.

Rest of the details as in Experiment 1.

Results:- Results are presented in Appendix I, Tables 21 to 24. Table 21 gives the developmental period of T. pupivora when bred on pupa of O. exivinacéa. The developmental period varies from 17 to 20 days, the average being 18.7 days. Table 22 gives the number of parasites that emerged from each pupa and their sex ratio. It is seen that the number of parasites emerging from a pupa varies from 135 to 351, the average being 235.4. The ratio of male : female parasites is seen to be on an average 1:17.943. Table 23 shows that the longevity of the parasites emerging from the pupa of O. exvinacea is on an average 4.874 days. Table 24 gives the data on the measurements of length, width of head and width of thorax of male and female parasites bred on pupa of O. exvinacea. The measurements (average of 50 insects) are seen to be 1.156, 0.359, 0.323 and 1.234, 0.413, 0.345 mm. respectively.

Experiment 7

Host pupa	Nephantis serinopa
Experimental details	
Period during which the experiment was conducted and concluded:	22--11--1962 to 16--12--1962
Temperature during the experiment:	Mnm. 80° - 84° F. Mxm. 82° - 86° F.
Relative humidity during the experiment:	81% - 95%

Details of weight of pupa and dates of exposure and emergence of parasites are given in table 25.

Rest of the details as in Experiment 1.

Results:- Results are presented in Appendix I, Tables 25 to 28. Tables 25 show that the developmental period of T. pupivora when bred on the pupa of N. serinopa varies from 17 to 18 days with an average of 17.3 days. From Table 26 it may be seen that the number of parasites emerging from a pupa varies from 141 to 286, the average being 227.7 and that the ratio of male : female parasites is 1:12.859. Table 27 shows that the longevity of parasites emerging from the pupa of N. serinopa is on an average of 3.781 days. Table 28 gives the data on the average measurements of length, width of head and width of thorax of male and female parasites bred on the pupa of N. serinopa. It may be seen that the measurements (average of 50 insects) are 1.121, 0.336, 0.304 and 1.181, 0.391, 0.313 mm. respectively.

Experiment 8

Host pupa:	Gracillaria soyella
Experimental details	
Period during which the experiment was conducted and concluded:	28--1--1963 to 17--2--1963
Temperature during the experiment:	Mnm. 78° - 80° F. Mxm. 80° - 86° F.
Relative humidity during the experiment:	79% - 89%

Details regarding the weight of pupa and dates of exposure and emergence of parasites are given in Table 29.

Rest of the details as in Experiment 1.

Results:- Results are presented in Appendix 1, Table 29 to 32. Table 29 gives the developmental period of T. pupivora when bred on pupae of G. soyella which shows that the developmental period varies from 16 to 18 days, the average being 17 days. From Table 30 it is seen that the number of parasites emerging from a pupa varies from 12 to 17, the average being 14.7 and that the ratio of male : female parasites is on an average 1:9.050. Table 31 shows that the longevity of parasites emerging from the pupa of

G. soyella is on an average 1.445 days. Table 32 which gives the data on the average measurements of length, width of head and width of thorax of male and female parasites bred on pupa of G. soyella shows that the measurements, average of 50 insects are 0.998, 0.308, 0.278 and 1.124, 0.372, 0.319 mm. respectively.

II. Studies on the effect of induced superparasitism on T.pupivora

A series of 4 experiments were conducted with a view to ascertain the effect of 4 levels of induced superparasitism by T. pupivora on the total number of adults produced, sex ratio, developmental period, longevity and size of parasites when bred on pupa of Plusia peponis.

Experiment 9 — Pupae parasitised by five parasites

Experimental details

Number of pupa used:	10
Age of pupa:	Less than 24 hours
Age of parasites used for parasitisation:	Less than 24 hours
Period during which the experiment was conducted and concluded:	18--1--1963 to 14--2--1963
Temperature during the period of experiment:	Mnm. 78°- 80° F. Mxm. 80°- 86° F.
Relative humidity during the period of experiment	79% - 90%

Procedure - Same as in Experiment 1.

Details regarding the weights of individual pupa used, of exposure and emergence of parasites are given in Table 38.

Results:- Results of the experiment are given in Tables 38 to

41. (Appendix I). A perusal of the data in Table 38 shows that the developmental period varies from 17 to 22 days, the average being 19.6 days. From Table 39 it may be seen that the number of parasites emerging from a pupa varies from 266 to 461, the average being 372.9. The ratio of male : female parasites is seen to be on an average 1:29.242. Table 40 gives the data on the survival of the adult parasites following their emergence and their calculated longevity. It will be observed that the parasites survive for an average period of 3.799 days. Table 41 shows that the average measurements (of 50 parasites) of length, width of head and width of thorax of male and female parasites as 1.186, 0.357, 0.320 and 1.278, 0.437, 0.350 mm. respectively.

Experiment 10

Pupae parasitised by 10 parasites

Experimental details

Period during which the experiment was conducted and concluded:	18--1--1963 to 19--2--1963
Temperature during the period of experiment:	Mnm. 78° - 80° F. Mxm. 80° - 86° F.
Relative humidity during the period of experiment:	79% - 90%

Details of weight of pupa and dates of exposure and emergence of parasites are given in Table 42.

Rest of the details as in Experiment 9.

Results:- Results are presented in Appendix I, Tables 42 to 45. Table 42 shows that the developmental period varies from 16 to 20 days, the average being 17.7 days. From table 43 it is seen that the number of parasites emerging from a pupa varies from

318 to 529 the average being 408.7. The ratio of male : female parasites is 1:27.992. Table 44 shows that the parasites that emerge from the pupa of P. peponis exposed to ten parasites survive on an average for a period of 4.255 days. The data on the measurements of length, width of head and width of thorax of male and female parasites are presented in Table 45. The average measurements are 1.121, 0.338, 0.312 and 1.177, 0.392, 0.312 mm. respectively.

Experiment 11

Pupae parasitized by 15 parasites

Experimental details

Period during which the experiment was conducted and concluded:	19--1--1963 to 21--2--1963
Temperature during the period of experiment:	Mnm. 78° - 80°F. Mxm. 80° - 86°F
Relative humidity during the experiment:	79% - 90%

Details of weight of pupa and dates of exposure and emergence of parasites are given in Table 46.

Rest of the details as in Experiment 9.

Results:- Results are presented in Appendix I, Table 46--49. From Table 46 that the developmental period varies from 17 to 18 days with an average 17.3 days. Table 47 shows that the number of parasites emerging from a pupa varies from 401 to 528, the average being 453.8. The ratio of male : female parasites is seen to be on an average 1:26.454. Table 48 shows the longevity of the parasites and it is seen that the average period of survival for the parasites is 4.752 days. Table 47 gives data on measurements of length, width of head and width of thorax of male and female parasites. The average measurements are 1.110, 0.336, 0.301 and 1.172, 0.391, 0.312 mm. respectively.

Experiment 12

Pupae parasitised by 20 parasites

Experimental details

Period during which the experiment was conducted and concluded:	20-1-1963 to 19-2-1963
Temperature during the experiment:	Mnm. 78° - 80° F. Mxm. 80° - 86° F.
Relative humidity during the experiment:	79% - 89%

Details of weight of host pupa and dates of exposure and emergence of parasites are given in Table 50.

Rest of the details as in Experiment 9.

Results:- Results are presented in Appendix I, Tables 50 to 53. Table 50 shows that the developmental period of the parasite varies from 17 to 18 days, with an average of 17.1 days. Table 51 gives the number of parasites emerged and their sex ratio. The number of parasites emerging from a pupa varies from 612 to 901 the average being 742.8. The ratio of male : female parasites is seen to be on an average 1:15.49. Table 51 shows that the average period of survival of the parasite is 3.142 days. Table 53 gives the data on the measurements of length, width of head and width of thorax of male and female of parasites and these measurements are 1.037, 0.310, 0.284 and 1.080, 0.359, 0.304 mm. respectively.

DISCUSSION

I. Effect of different hosts on the number of adults of *T. pupivora* produced

(a) Relation between weight of host pupa and number of adults of *T. pupivora* produced

With a view to ascertain if there exists any relation between weight of host pupa and the number of adults of *T. pupivora* produced, the coefficient of correlation has been calculated taking the weight of host pupae and the number of parasites obtained as the two variables. For this all the 80 host pupae under study have been taken as a sample of the population without taking into consideration the effect, if any, of species concerned. The correlation coefficient (r) is found to be 0.764. Test for significance shows the tabulated value of (r) for 78 d.f at 1% level as 0.2867, indicating significant correlation between the weight of host pupa and the number of parasites produced.

Further, the regression of the number of parasites (b) on weight of host pupa (a) was calculated and found to be $b = 911.875a + 94.109$ and Fig. 1 gives the best fitting line for the data. In the test for regression the calculated F ratio is 126.76 as against the tabulated value of 7.008 for 1 and 78 d.f. at 1% level, which shows that the regression coefficient is highly significant.

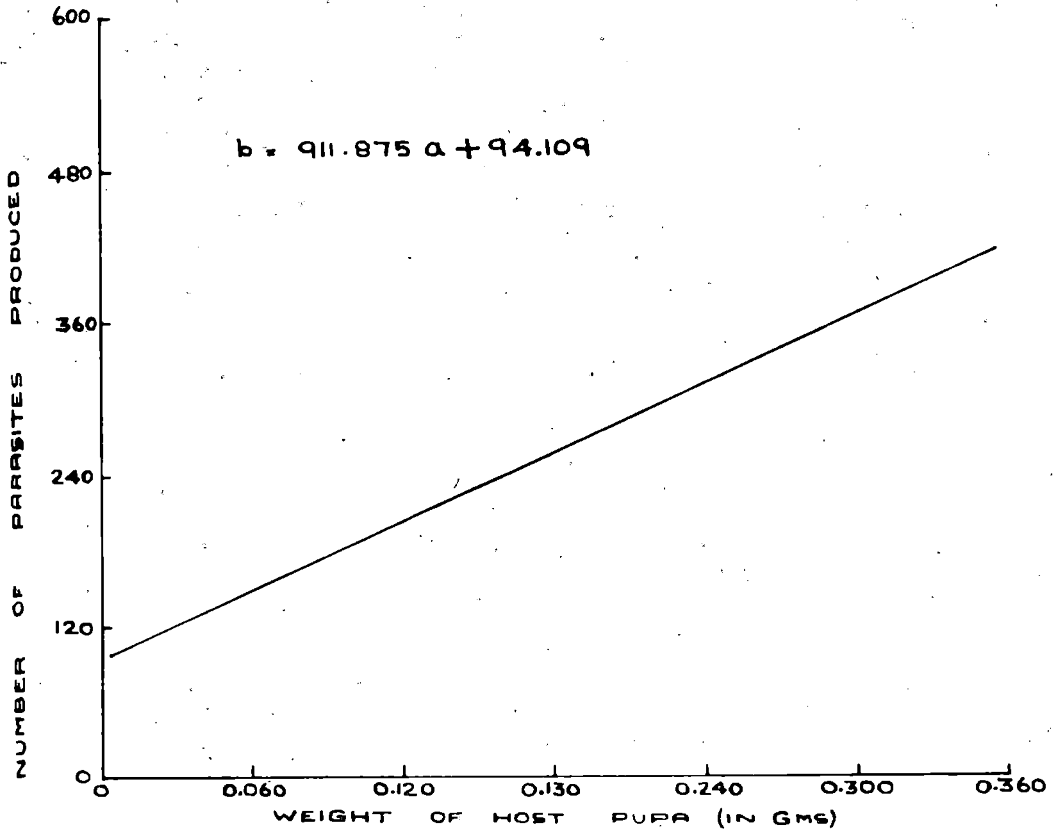


FIG.1. REGRESSION LINE FOR THE NUMBER OF PARASITES PRODUCED (b) ON WEIGHT OF HOST PUPA (a)

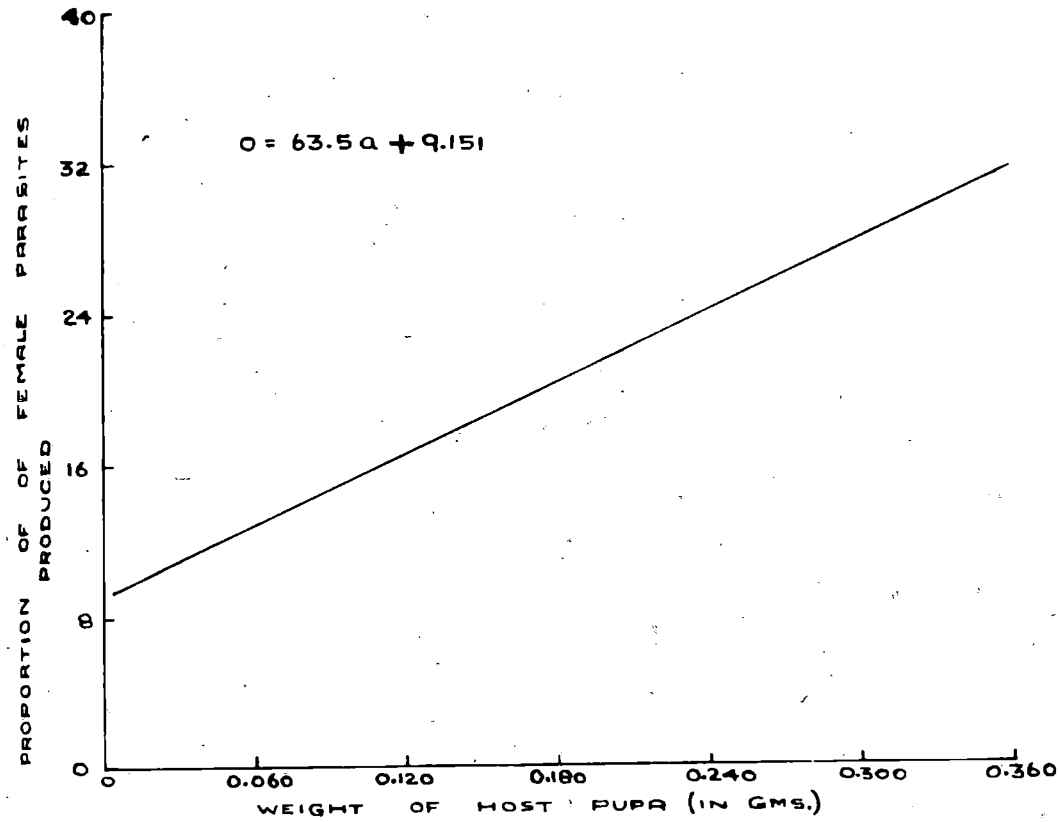


FIG.2. REGRESSION LINE FOR THE SEX RATIO OF T. PUPIVORA (PROPORTION OF FEMALE PARASITES PRODUCED) (O) ON THE WEIGHT OF HOST PUPA (a)

The results of these analyses thus show that there exists a positive linear correlation between the size of host pupa and the number of parasites produced. This observation agrees with that made by Ullyet (1936) on *Trichogramma lutea*.

(b) Number of adults produced by different species of host pupae

The average number of parasites produced by the different species of host pupae are given in Table 33.

Table 33

Average number of adults of *T. pupivora* produced by different species of host pupae

Sl. No.	Name of pupa	Weight of pupa in Gms. average.	Number of parasites produced.
1.	*Phytometra peponis*	0.320	372.9
2.	*Prodenia litura*	0.172	209.0
3.	*Orthaga exvinacea*	0.117	235.4
4.	*Sylepta derogata*	0.085	167.1
5.	*Lampides boeticus*	0.082	194.5
6.	*Margaronia indica*	0.070	163.7
7.	*Nephantis serinopa*	0.066	227.7
8.	*Gracillaria soyella*	0.004	14.7

It will be seen that *Phytometra* pupa produces the largest number of parasites followed in the descending order by *Orthaga*, *Nephantis*, *Prodenia*, *Lampides*, *Sylepta*, *Margaronia* and *Gracillaria*.

From the statistical analysis using the analysis of covariance technique the following conclusion has been arrived at.

1 <u>3 2 7 5 4 6</u> 8

in which the numbers denote the different species as:-

1. *Phytometra peponis*
2. *Prodenia litura*
3. *Orthaga exvinacea*
4. *Sylepta derogata*
5. *Lampides boeticus*
6. *Margaronia indica*
7. *Nephantis serinopa*
8. *Gracillaria soyella*

The details of the calculations are given in Appendix IIa.

From this it is evident that *Phytometra* pupa produces significantly higher number of parasites than the other host pupae. Among the rest, there is no significant difference in the number of parasites produced by the host pupae 2 to 7 while pupa 8 produces the least number of parasites.

II. Effect of host on sex ratio of *T. pupivora*

(a) Relation between the weight of host pupa and sex ratio of *T. pupivora*

Correlation coefficient calculated from all the 80 host pupae irrespective of the species is 0.893. The tabulated value of 'r' for 78 d.f. at 1% level was found to be 0.2867. This shows that the correlation between the weight of host pupa and sex ratio is highly significant.

The regression of the sex ratio (0) on the weight of host pupa (a) is calculated to be 0 = 63.5a + 9.151. In the regression test, calculated F ratio is 282 as against the tabulated value 7.008, for 1 and 78 d.f at 1% level. Thus the regression coefficient also is highly significant. This is graphically represented in Fig. 2.

The above analyses show that the proportion of the number of female parasites of _T. pupivora_ produced, increases as the size of the pupa increases. Similar observations on the effect of host on sex ratio were made by Chewyreuv (1913) on _Pimpla instigator_, _Exenterus_ sp. and _Campoplex_ sp., Smith (1932) on _Alysia manducator_, Seyrig (1935) on _Ecthromorpha hyalina_ and _Pimpla maculiscaposa_, Brunson (1937) on _Tiphia popiliavora_ and Taylor (1937) on Chalcid parasite _Pleurothrops parvulus_.

(b) _Sex ratio of T. pupivora produced by different species of host pupa_

Table 34 shows that _Phytometra_ pupa produces the largest proportion of females followed in the descending order by _Orthaga_, _Prodenia_, _Lampides_, _Sylepta_, _Margaronia_, _Nephantis_ and _Gracillaria_.

Analysis of covariance shows that with respect to the sex ratio of the parasites produced, the different host pupae can be grouped as follows:-

1   2   3   5   4   6   7   8

(The numbers are similar as referred to earlier. Details of calculations are given in Appendix II b)

It may be observed that Phytometra (1) pupa produces significantly larger proportion of female parasites than the other host pupae. Further in the proportion of females produced, pupae 2, 3 and 5 differ significantly from pupa 8 while there exists no difference among the pupae 2 to 7.

Table 34

Sex ratio of *T. pupivora* produced by different species of host pupa

Sl. No.	Name of pupa	Weight of pupa in Gms. av.	Number of male	Number of female	Sex ratio
1.	*Phytometra peponis*	0.320	12.2	360.7	29.822
2.	*Prodenia litura*	0.172	11.5	197.5	17.270
3.	*Orthaga exvinacea*	0.117	12.8	222.6	17.943
4.	*Sylepta derogata*	0.085	10.7	156.4	14.993
5.	*Lampides boeticus*	0.082	12.1	182.4	15.458
6.	*Margaronia indica*	0.070	11.9	151.8	13.699
7.	*Nephantis serinopa*	0.066	16.7	211.0	12.859
8.	*Gracillaria soyella*	0.004	1.6	13.0	9.050

III. Effect of host on the developmental period of *T. pupivora*

(a) Relation between the weight of host pupa and the developmental period of *T. pupivora*

Correlation coefficient calculated from all the 80 host pupae irrespective of the species is 0.647. The tabulated value of 'r' for 78 d.f. at 1% level is 0.2867. Thus a highly significant correlation between the weight of host pupa and developmental period is indicated.

The regression of the developmental period (k) on the weight of host pupa (a) is calculated to be $k = 9.625a + 16.965$. In the test for regression the calculated F ratio is 63.31, while the tabulated value for 1 and 78 d.f. at 1% level is 7.008. Thus the regression also is significant. This is represented graphically in Fig. 3. It is evident that there exists a positive linear correlation between the weight of host pupa and the duration of development. The only other study on the effect of the size of the host on the developmental period of a parasite is that of Salt (1940) on *Trichogramma evanescens*. He also observed similar correlations as observed in the present studies.

(b) Developmental period of *T. pupivora* in different species of host pupae

From table 35 it may be seen that the total duration of development is longest in *Phytometra* pupa followed by the other host pupae in the order, *Orthaga* > *Prodenia* = *Lampides* > *Margaronia* = *Nephantis* > *Gracillaria* > *Sylepta*.

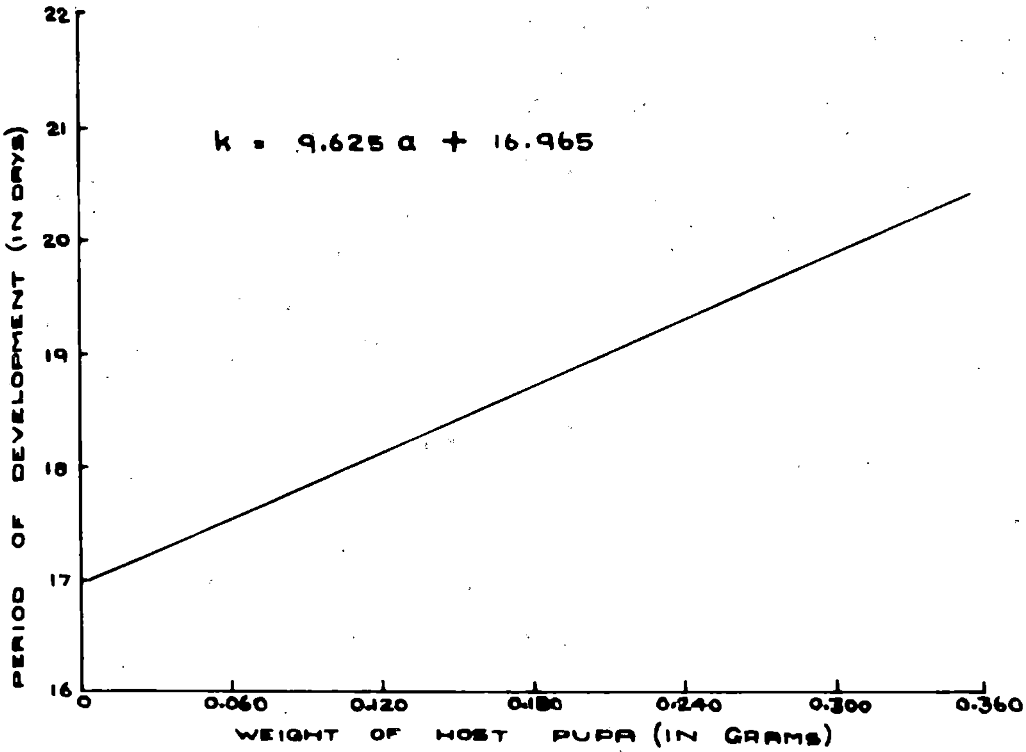


FIG. 3. REGRESSION LINE FOR THE PERIOD OF DEVELOPMENT (k) ON THE WEIGHT OF HOST PUPA (a)

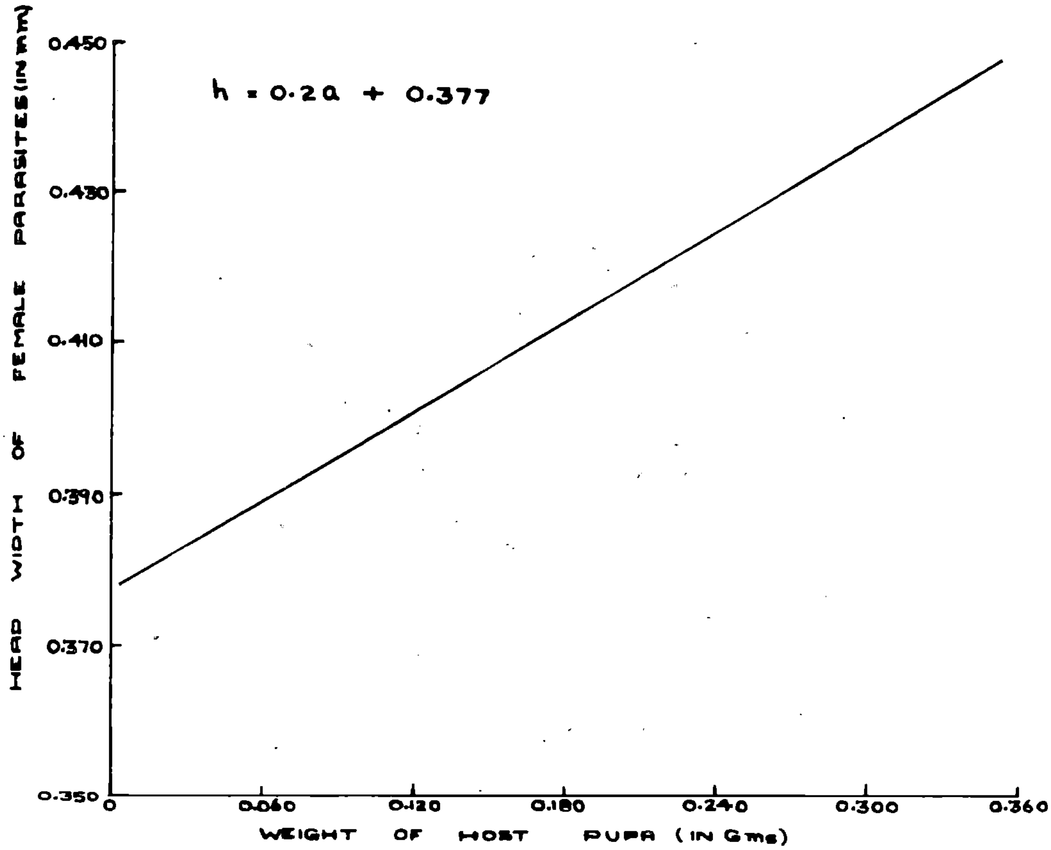


FIG. 4. REGRESSION LINE FOR THE SIZE OF *T. PUPIVORA* (HEAD WIDTH OF FEMALE PARASITES (h) ON THE WEIGHT OF HOST PUPA (a)

Table 35

Average duration of development of *T. pupivora* in different species of host pupa

Sl. No.	Name of pupa	Weight of pupa in Gms. (av.)	Duration of Development in days
1.	*Phytometra peponis*	0.320	19.6
2.	*Prodenia litura*	0.172	18.5
3.	*Orthaga exvinacea*	0.117	18.7
4.	*Sylepta derogata*	0.085	16.9
5.	*Lampides boeticus*	0.082	18.5
6.	*Margaronia indica*	0.070	17.3
7.	*Nephantis serinopa*	0.066	17.3
8.	*Gracillaria soyella*	0.004	17.0

The conclusions drawn from the analysis of covariance may be summarised as:-

$$\underline{1\quad \overline{3\quad 2\quad 5}}\;\overline{\quad 6\quad 7\quad 4\quad 8}$$

This explains that the developmental period of the parasites is significantly longer in the pupa of *Phytometra* (1) than in the pupae 6, 7, 4 & 8 and is not significantly longer than in the pupae 3, 2 and 5. (Details of calculations given in Appendix IIc)

IV. Effect of host on the longevity of adults of *T. pupivora*

(a) Relation between weight of host pupa and longevity of *T. pupivora*

The correlation coefficient calculated from all the 80 host pupae irrespective of the species is 0.122. The tabulated value of 'r' for 78 d.f. at 5% level is 0.2136. This indicates that there appears to be no significant correlation between the size of host pupa and the longevity of the adult parasites which emerge from them.

(b) Longevity of adults of *T. pupivora* produced by different species of host pupae.

The average longevity of *T. pupivora* adults bred on different host pupae are given in Table 36.

Table 36:

Average longevity of adults of *T. pupivora* bred on different species of host pupae

Sl. No.	Name of pupa	Weight of pupa (average)	Longevity in days		
			Male	Female	Whole
1.	*Phytometra peponis*	0.320	2.146	3.368	3.282
2.	*Prodenia litura*	0.172	1.721	4.273	4.066
3.	*Orthaga exvinacea*	0.117	2.158	5.118	4.874
4.	*Sylepta derogata*	0.085	1.952	5.219	4.963
5.	*Lampides boeticus*	0.082	1.303	2.351	2.292
6.	*Margaronia indica*	0.070	1.336	2.340	2.298
7.	*Nephantis serinopa*	0.066	1.631	3.919	3.781
8.	*Gracillaria soyella*	0.004	1.050	1.535	1.455

It is seen that the longevity of parasites is greatest when bred on Sylepta pupae. It decreases in the descending order in other hosts as Orthaga, Prodenia, Nephantis, Phytometra, Margaronia, Lampides and Gracillaria.

By the application of analysis of covariance the following conclusions has been made:-

4 3 7 2 6 5 8 1

(Details of calculations given in Appendix IId)

This shows that the longevity of parasites produced in pupa of Sylepta (4) is significantly longer than that of the parasites produced in pupa of Phytometra (1) and that it does not vary from the longevity of parasites produced by pupae 3, 7, 2, 6, 5 and 8.

V. Effect of host on the size of T. pupivora

(a) Relation between the weight of host pupa and the size of T. pupivora

To study this, the head width of female parasites has been taken as a measure of the size of parasites. The correlation coefficient between the head width of female parasites and the weight of host pupa has been calculated to be 0.556, while the tabulated value of 'r' for 78 d.f. at 1% level is 0.2867. This indicate a significantly high correlation between the two variables.

The regression of the size of the parasites (h) on the weight of host pupae (a) is $h = 0.2a + 0.377$. In the regression test the calculated F ratio is 20.9 as against the tabulated value 7.008 for 1 and 78 d.f. at 1% level. Thus the regression also is highly significant. It is represented graphically in Fig. 4. All these go to show that there exists a highly significant and positive linear correlation between the weight of host pupae and the size of parasites. Similar results were obtained by many previous workers like Ratzburg (1844), Toyama (1906), Morril (1907), Chewyreuv (1913), Thompson (1923), Mickel (1924), Flanders (1930), Lathrop and Newton (1933), Jakson (1937) and Salt (1940) in various other parasites.

(b) Size of adults of *T. pupivora* bred on the different species of host pupae

The various measurements of the male and female adult parasites bred on the different species of host pupae are given in Table 37. With a view to understand the extent of variation existing in the size of the parasites produced in the different host pupae, analysis of covariance was done using the head width of female parasites as the effect. The F ratio was not found to be significant, indicating that there is no significant difference in the size of parasites emerging from the different species of hosts.

Table 37

Average measurements of adults of T. pupivora bred on different species of host pupae

Sl. No.	Name of pupa	Weight of pupa in Gms. (av.)	Measurements in mm.					
			Length		Width of head		Width of thorax	
			Male	Female	Male	Female	Male	Female
1.	Phytometra peponis	0.320	1.210	1.273	0.365	0.431	0.330	0.353
2.	Prodenia litura	0.172	1.142	1.205	0.333	0.401	0.302	0.322
3.	Orthaga exvinacea	0.117	1.156	1.234	0.359	0.413	0.323	0.345
4.	Sylepta derogata	0.085	1.166	1.234	0.350	0.411	0.323	0.333
5.	Lampides boeticus	0.082	1.088	1.152	0.327	0.398	0.300	0.325
6.	Margaronia indica	0.070	1.137	1.137	0.343	0.379	0.318	0.333
7.	Nephantis serinopa	0.066	1.121	1.181	0.336	0.391	0.304	0.313
8.	Gracillaria soyella	0.004	0.998	1.124	0.308	0.372	0.278	0.319

VI. Effect of different levels of induced superparasitism on the number of adults of T. pupivora produced by pupae of Phytometra peponis

The average numbers of parasites produced in P. peponis pupa as a result of parasitisation by varying numbers of parasites are given in Table 54.

It will be seen that the maximum number of parasites is produced when the pupa is parasitised by 20 parasites, while the numbers of parasites produced when parasitised by 15, 10 and

5 parasites follow a descending order.

Table 54

Average number of adults of *T. pupivora* produced in pupa of *P. peponis* when parasitised by different numbers of parasites

Sl. No.	Number of parasites parasitising a pupa.	Weight of host pupa average	Number of parasites produced.
1.	5	0.317	345.9
2.	10	0.312	408.7
3.	15	0.297	453.8
4.	20	0.305	742.8

In order to understand whether there exists any correlation between the different levels of induced superparasitism and the number of adults of *T. pupivora* produced, the coefficient of correlation has been calculated. For this all the 40 host pupae under study have been considered as a sample of the population. The different levels of superparasitism and the number of parasites emerged are considered as the two variables. The correlation coefficient (r) is calculated to be 0.807. Test for significance shows the tabulated value of r for 38 d.f. at 1% level as 0.3732, indicating significant correlation between the different levels of superparasitism and the number of parasites emerged.

Further, the regression of the number of parasites (b) on different levels of superparasitism (x) has been calculated. It is seen that there is no linear regression. When these two are plotted the points have been seen to lie very closely along a 2nd degree curve (Fig. 5). The equation of which is $b = 2.252x^2 - 31.564x + 460.35$. In the test for regression, the calculated F ratio is 57 as against the tabulated value of 5.243 for 2 nd 37 degrees of freedom at 1% level and this shows that the regression coefficient is highly significant.

The results of the analyses thus show that there exists a highly significant and positive correlation between the different levels of superparasitism and the number of parasites emerged.

This observation agrees with that of Salt (1940) on Trichogramma evanescens.

Analysis of covariance has enabled the following conclusion:

20 $\underline{15 \quad 10}$ 5

in which the numbers denote the different numbers of parasites used for parasitisation. (Details of calculations given in Appendix II

From this also it is evident that a significantly large number of parasites is produced when pupae are parasitised by 20 parasites. Further, the number of parasites produced when the pupae are parasitised by 15 parasites is significantly larger than when parasitised by 5 parasites, but is not significantly larger than when parasitised by 10 parasites.

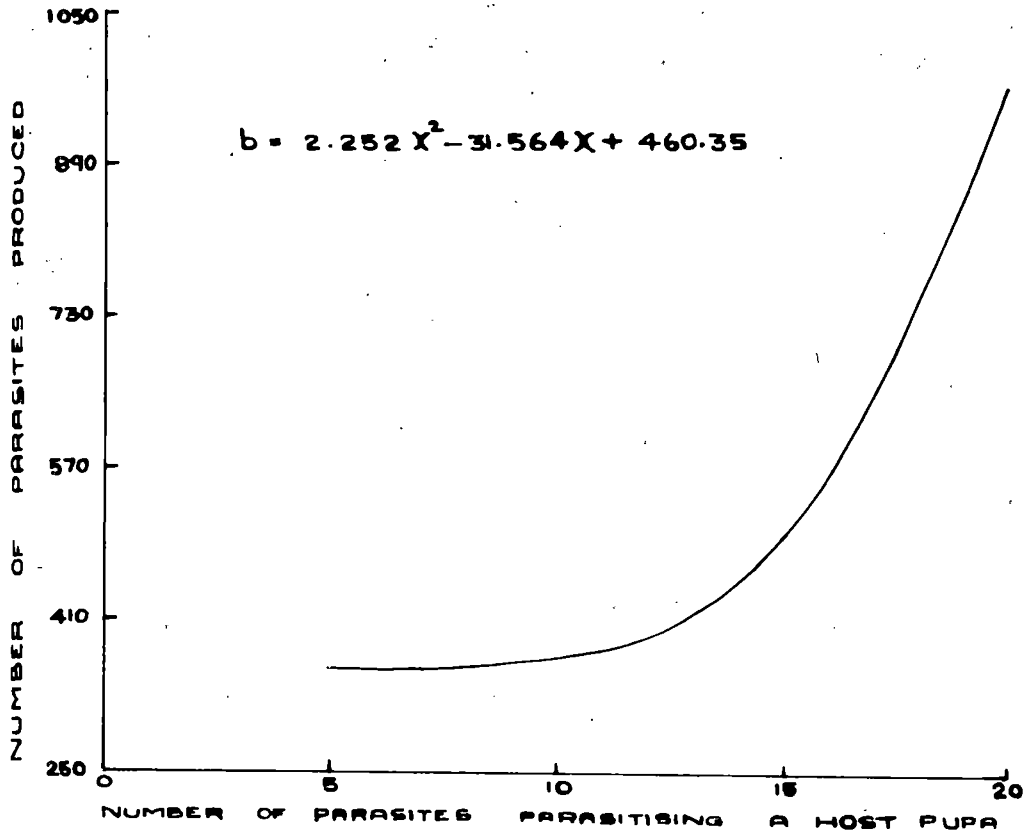


FIG.5. REGRESSION LINE FOR THE NUMBER OF PARASITES PRODUCED (b) ON THE NUMBER OF PARASITES PARASITISING A HOST PUPA(X)

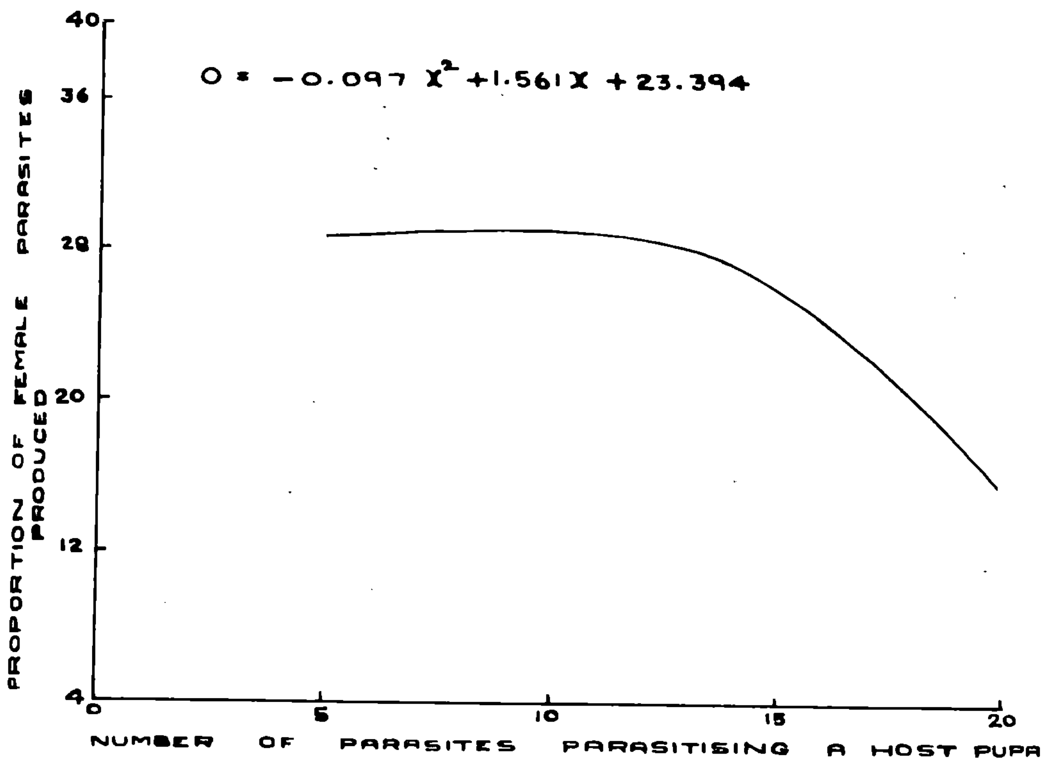


FIG.6. REGRESSION LINE FOR THE SEX RATIO OF T.PUPIVORA (O) (THE PROPORTION OF FEALE PARASITES PRODUCED) ON THE NUMBER OF PARASITES PARASITISING A HOST PUPA (X)

VII. Effect of different levels of induced superparasitism on the sex ratio of *T. pupivora* bred on pupae of *P. peponis*:

Table 55 shows that the largest proportion of females is produced when the pupae are parasitised by 5 parasites each. This proportion shows a progressive decrease corresponding with the progressive increase in the level of superparasitism from 5 to 20.

Table 55

Sex ratio of *T. pupivora* bred on pupa of *P. peponis* when parasitised by varying numbers of parasites

Sl. No.	Number of parasites parasitising a pupa	Weight of host pupa in Gms. (average)	Number of male	Number of female	Sex ratio
1.	5	0.317	11.5	334.4	29.242
2.	10	0.312	14.6	394.1	27.992
3.	15	0.297	18.9	434.9	26.454
4.	20	0.305	46.8	696.0	15.490

Coefficient of correlation of these two variables is calculated to be-0.605. Its tabulated value for 38 d.f. at 1% level is 0.3732. Thus a significant negative correlation between levels of superparasitism and proportion of female parasites is in evidence. The regression of the sex ratio (O) on the different levels of superparasitism (x) is calculated to be $0 = -0.097x^2 + 1.561x + 23.394$. In the regression test the calculated F ratio is 15.69 as against the tabulated value of 5.243 at 2 and 37 degrees of freedom at 1% level, indicating that the regression coefficient is highly significant. This is graphically represented in Fig. 6. The above analysis thus shows that the proportion of the number of females of T. pupivora produced decreases as the level of superparasitism increases.

Similar observations of the effect of induced superparasitism on sex ratio of parasites were made by Salt (1936) on *Trichogramma evanescens*, Narayanan et. al. (1945) on *Bracon (Microbracon) gelachiae* and Narayanan and Subba Rao (1955) on *Microbracon gelechiae*.

The analysis of covariance shows that with respect to the sex ratio of the parasites produced, the different levels of superparasitism can be grouped as follows:-

<u>5 10 15</u> 20

(Details of calculations given in Appendix II g)

It may be observed that the significantly lowest proportion of females is produced when the pupae are parasitised by 20 parasites. There does not appear to be any significant difference in the proportion of females produced when the pupae are parasitised by 5, 10 or 15 parasites.

VIII. Effect of different levels of superparasitism on the developmental period of *T. pupivora* bred on pupae of *P. peponis*

From the Table 56 it may be seen that the total duration of development is longest when the pupae are parasitised by 5 parasites, followed in the descending order by parasitisation by 10, 15 and 20 parasites.

Table 56

Average duration of development of *T. pupivora* in the pupa of *P. peponis* when parasitised by varying numbers of parasites

Sl. No.	Number of parasites parasitising a pupa	Weight of pupa in Gms. (average)	Duration of development in days
1.	5	0.317	19.6
2.	10	0.312	17.7
3.	15	0.297	17.3
4.	20	0.305	17.1

Correlation coefficient (r) calculated is - 0.670 while the tabulated value of 'r' for 78 d.f. at 1% level is 0.3732, indicating significant correlation between different levels of superparasitism and developmental period. The regression of the period of development (k) on different levels of superparasitism (x) is calculated to be $k = 0.017\ x^2 - 0.583x + 22.025$. In the regression test, the calculated F ratio is 18.5 as against the tabulated value of 5.243 for 2 and 37 d.f. at 1% level, which shows that the regression coefficient is highly significant. This is graphically represented in Fig. 7. Thus it is evident that there exists a negative correlation between different levels of superparasitism and duration of development.

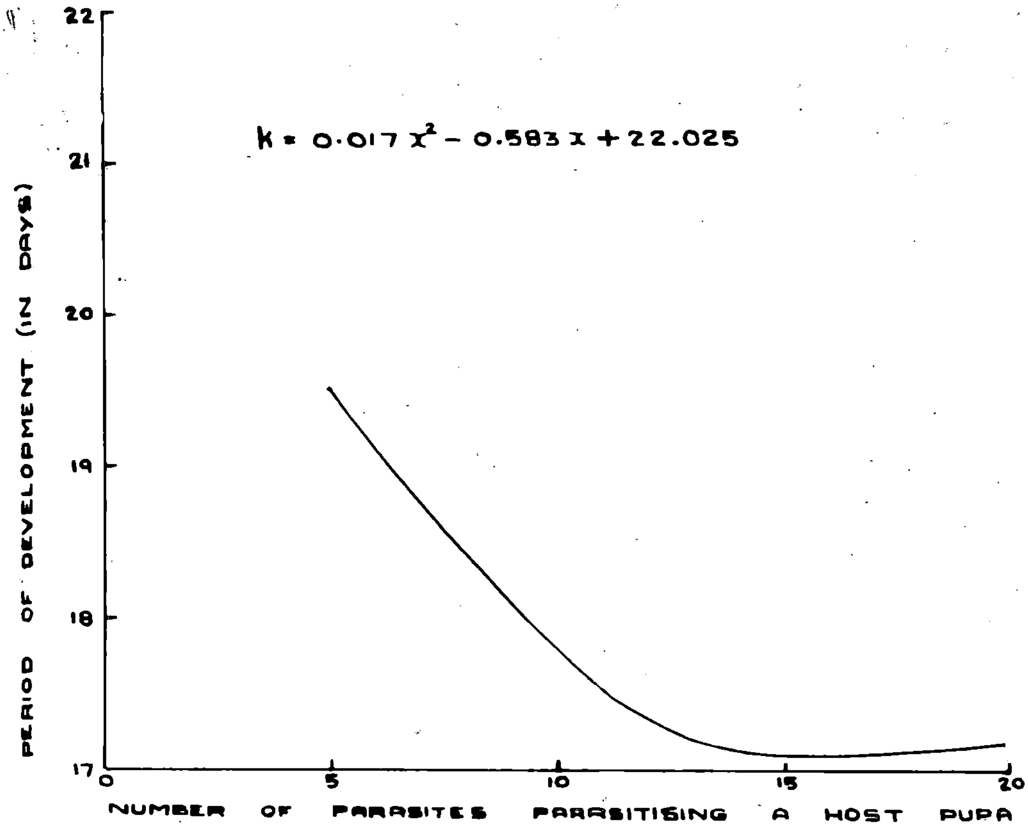


FIG.7. REGRESSION LINE FOR THE PERIOD OF DEVELOPMENT OF *T. pupivora* (k) ON NUMBER OF PARASITES PARASITISING A HOST PUPA (X)

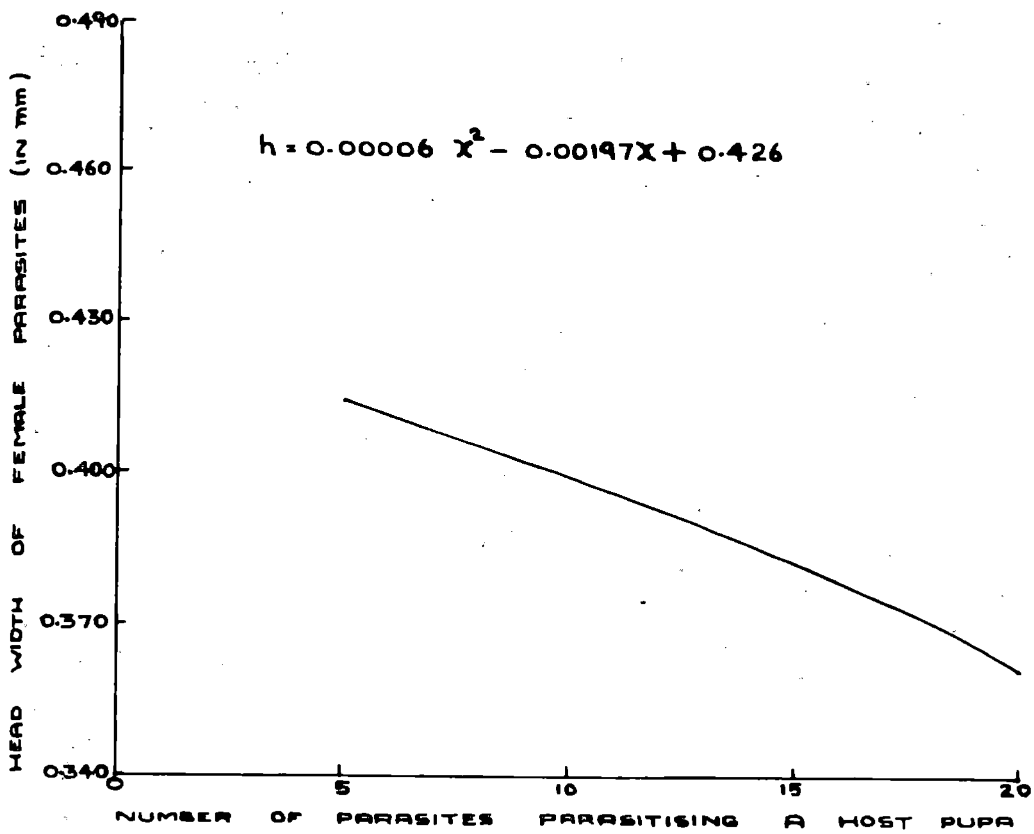


FIG.8. REGRESSION LINE FOR THE SIZE OF *T. pupivora* (HEAD WIDTH OF FEMALE PARASITES) (h) ON THE NUMBER OF PARASITES PARASITISING A HOST PUPA (X)

The conclusion drawn from the analysis of covariance may be summarised as follows:

$$5 \quad \underline{10 \quad 15 \quad 20}$$

This explains that the developmental period of *T. pupivora* is significantly longest when the pupae are parasitised by 5 parasites. No significant difference in developmental period of *T. pupivora* is found when the pupae are parasitised by 10, 15 or 20 parasites. (Details of calculations given in Appendix II h)

IX. Effect of different levels of induced superparasitism on longevity of adults of *T. pupivora* bred on pupae of *P. peponis*

Table 57 indicates that the average longevity of the parasites is highest when the pupae are exposed to fifteen parasites followed by the other levels of parasitism in the order 10 < 5 < 20.

The correlation coefficient (r) calculated is - 0.117, the tabulated value of 'r' being 0.3732 for 38 d.f. at 1% level and 0.3126 at 5% level. Thus there appears to be no significant correlation between the different levels of superparasitism and longevity of parasites.

Analysis of covariance gives the following conclusion.

$$\underline{15 \quad \overline{10}}\overline{\quad}\underline{\overline{5} \quad 20}$$

(Details of calculations given in Appendix II i)

This indicates that the longevity of parasites is significantly longer when pupae are parasitised by 15 parasites than when parasitised by 5 or 20 parasites but is not significantly different from that when parasitised by 10 parasites. Further, longevity of parasites is significantly longer when pupae are parasitised by 10 parasites than when parasitised by 20 parasites but is not significantly different from that when parasitised by 5 parasites.

Table 57

Average longevity of adults of *T. pupivora* bred on pupae of *P. peponis* when exposed to different levels of superparasitism

Sl. No.	Number of parasites parasitising a pupa	Weight of pupa in Gms. (av.)	Longevity in days		
			Male	Female	Whole
1.	5	0.317	2.170	3.852	3.799
2.	10	0.312	2.020	4.434	4.255
3.	15	0.297	1.617	5.080	4.752
4.	20	0.305	1.533	3.202	3.142

X. Effect of different levels of induced superparasitism on the size of *T. pupivora* bred on pupae of *P. peponis*

The various average measurements of the male and female parasites bred on pupae of *P. Peponis* when parasitised by different numbers of parasites are given in Table 58.

Table 58

Average size of adults of T. pupivora bred on pupae of P. peponis when parasitised by varying numbers of parasites:

Sl. No.	Number of parasites parasitising a pupa.	Weight of pupa in Gms. (av.)	Measurements in mm.					
			Length		Width of head		Width of thorax	
			Male	Feamle	Male	Female	Male	Female
1.	5	0.317	1.186	1.278	0.357	0.417	0.320	0.350
2.	10	0.312	1.121	1.177	0.338	0.392	0.312	0.311
3.	15	0.297	1.110	1.172	0.336	0.391	0.301	0.312
4.	20	0.305	1.037	1.080	0.310	0.359	0.284	0.304

The coefficient of correlation 'r' between the head width of female parasites (which is taken as a measure of size) and different levels of induced superparasitism is found to be -0.612, while the tabulated value of 'r' for 38 d.f. at 1% level is 0.3732. Highly significant negative correlation between size of parasites and different levels of superparasitism is thus indicated. The regression of the size of parasite (h) on the different levels of induced superparasitism (x) is $h = -0.00006x^2 - 0.00197x + 0.426$. In the regression test the calculated F ratio is 10.7 as against the tabulated value of 5.243 for 2 and 37 d.f. at 1% level. Thus the regression also is highly significant. It is represented graphically in Fig.8. It is thus evident that as the number of parasites parasitising a pupa increases the size of the emerging parasites show a corresponding reduction in size.

Similar results were obtained by Flanders (1936) on *Trichogramma* sp. and Salt (1940) on *Trichogramma evanescens*.

Analysis of covariance studies on this relation gives the following conclusion:-

5   15   10   20

This explains that the size of the emerging parasite is significantly bigger when pupae are parasitised by 5 parasites than when parasitised by 10 or 20 parasites, but does not vary significantly from that when parasitised by 15 parasites. Further, the emerging parasite appears to be significantly bigger when pupae are parasitised by 15 parasites than when parasitised by 20 parasites but no significant difference is seen when parasitised by 10 parasites. (Details of calculations given in Appendix II j).

SUMMARY AND CONCLUSIONS

The literature on the effect of host on parasites and that on *Trichospilus pupivora* has been reviewed.

The total number of adults produced, sex ratio, developmental period, longevity and size of *T. pupivora* were ascertained when bred on eight different species of host pupae, namely (1) *Phytometra peponis*, (2) *Prodenia litura*, (3) *Orthaga exvinacea*, (4) *Sylepta derogata*, (5) *Lampides boeticus*, (6) *Margaronia indica*, (7) *Nephantis serinopa*, and (8) *Gracillaria soyella*.

Correlation and regression studies show that there exist, a highly significant and positive linear correlation between the weight of the host pupa on the one hand and the number of parasites emerged, the proportion of females, the developmental period and the size of the parasites on the other. There does not appear to be any correlation between longevity of parasites and weight of host pupa.

Analysis of covariance shows that the different host pupae can be ranked as follows:-

(a) With respect to number of adult parasites produced:-

1 3 2 7 5 4 6 8

(b) With reference to the proportion of females produced:-

1 2 3 5 4 6 7 8

(c) With reference to developmental period:-

1 3 2 5 6 7 4 8

(d) With reference to longevity:-

4 3 7 2 6 5 8 1

It may thus be concluded that of the eight pupae under study, *Phytometra* pupa is the most suited for mass multiplication of *T. pupivora* in the laboratory because it produces the largest number of adult parasites and largest proportion of females.

The variations in the total number of adult parasites produced, sex ratio, period of development, longevity and size of *T. pupivora* bred on pupa of *P. peponis* when parasitised by 5, 10, 15 and 20 parasites have been ascertained.

Correlation and regression studies have shown that there exists a highly significant positive correlation between the levels of superparasitism (i.e. the number of parasites parasitising the pupa) and the number of adults produced and a significant negative correlation between the different levels of superparasitism on the one hand and the proportion of females produced, developmental period and size of the parasites on the other. There is no correlation between the number of parasites parasitising the pupa and the longevity of the parasites.

Based on analysis of covariance, the different levels of superparasitism with respect to the various characters of the parasite can be ranked thus:-

(a) With respect to number of parasites produced:-

20 15 10 5

(b) With respect to proportion of female parasites produced:-

5 10 15 20

(c) With respect to developmental period:-

5 10 15 20

(d) With respect to longevity:-

15 10 5 20

(e) With respect to size:-

5 15 10 20

It may thus be concluded that greater numbers of the parasite are produced when the host pupa is subjected to higher levels of superparasitism, but this advantage appears to be offset by the related reduction in the proportion of females.

REFERENCES

1. Ananthanarayanan, K.P. 1934. On the bionomics of a Eulophid (*Trichospilus pupivora* Ferriere) a natural enemy of the coconut caterpillar (*Nephantis serinopa* Meyr.) in South India. *Bul. Ent. Res.*, *25*: 55-61.

2. Bradley, W.G. & Arbuthnot, K.D. 1938. The relationship of host physiology to development of the Braconid parasite *Chelonus annulipes* Wesmael. *Ann. Ent. Soc. Amer.*, *31* : 359 - 365.

3. Brunson, M.H. 1937. Influence of instars of host larvae on the progeny of *Tiphia popilliavora* Rohwer, *Science*, *86* : 197 pp.

4. Cox, J.A. 1932. *Ascogaster Carpocapsae* Vierick, an important larval parasite of the Codling moth and Oriental fruitmoth. *N.Y. State Agr. Expt. Sta. Tech. Bull.*, 188, 26 pp.

*5. Chewyreuv, I.J. 1913. Le rôle des femelles dans la detérmination du sexe et leur descendance dans le groupe des Ichneumonides. *Soc. de Biol.* (Paris) *Compt. Rend.*, *74* :695-699.

6. Clausen, C.P. 1939. The effect of host size upon the sex ratio of Hymenopterous parasites and its relation to methods of rearing and colonisation. *J.N.Y. ent. Soc.*, *47* : 1 - 9.

7. Dowden, P.B. 1934. *Zenillia libatrix* Pantzer, a Tachinid parasite of the Gypsy moth and the Brown-tail moth. *Jour. Agr. Res.*, *48*: 97 - 114.

8. ---- 1935. *Brachymeria intermedia* Nees, a primary parasite and *B. compsilura* Cwfd. a secondary parasite, of the Gypsy moth. *Jour. Agr. Res.*, *50* : 495-523.

*9.	Faure, J.C.	1924.	Observations biologiques sur Bracon glaphyrus March. Rev. path. Veg., 11 : 70-72.
10.	Ferriere, C.	1930.	Notes on asiatic Chalcidoidea. Bull. Ent. Res., 21 : 358.
11.	Flanders, S.E.	1930.	Use of factitious host for rearing Trichogramma. Hilgardia, 4 : 465-501
*12.	----	1935 a.	Host influence on the prolificacy and size of Trichogramma. Pan - Pacific Ent., 11 : 175 - 177.
13.	----	1935 b.	An apparant correlation between the feeding habits of certain Pteromalids and the condition of their ovarian follicles. Ann. Ent. Soc. Amer., 28 : 438 - 444.
14.	----	1936 a.	A biological phenomenon affecting the establishment of Aphelinidae as parasites. Ent. Soc. Amer. Ann., 29 : 251 - 255.
15.	----	1936 b.	Coccidophilus citricola Brethes, a predator enemy of Red and Purple scales. J. econ. Ent., 29: 1023-1024.
16.	----	1942.	Abortive development in parasitic Hymenoptera by the food plant of the insect host. J. econ. Ent., 35 : 834-835.
17.	----	1945.	The role of spermatophore in the mass propagation of Macrocentrus ancylivorus. J. econ. Ent., 38 : 323-327.
18.	----	1946.	The mechanism of sex control in the Honeybees. J. econ. Ent., 39 : 379.
19.	Gilmore, J.U.	1938.	Notes on Apanteles congregatus Say, as a parasite of Tobacco hornworms. J. econ. Ent., 31 : 712-715.

*20. Hase, A. 1925. Beitrage zur lebensgeschichte der schlupwepe Trichogramma evanescens Westw. Biol. Reichsanst. f. Land U. Forstw. Arb., 14 : 171-224.

*21. --- & Albrecht, F.O. 1925. Beitrage zur lebensgeschichte der schlup wespe Trichogramma evanescens Westwood. Biol. Reichsanst. f. Land u. Forstw. Arb., 14 : 171 - 224.

22. Holdaway, F.G. & Smith, H.F. 1932. A relation between size of host puparia and sex ratio of Alysia manducator Pantzer. Austral. Jour. Expt. Biol. and Med. Sci., 10 : 247-259.

*23. Hutson, J.C. 1919. Report of the Entomologist. Ceylon Dept. Agri. Administr. Repts. for 1919, Peradeniya. pp. C8-C10.

24. ---- 1922. The coconut caterpillar (Nephantis serinopa). Trop. Agri, Peradeniya, 59 : 21-24.

25. Jayaratnam, T.J. 1941. A study of the control of the coconut caterpillar (Nephantis serinopa M.) in Ceylon with special reference to its Eulophid parasite, Trichospilus pupivora F., Trop. Agriculturist, 96 : 3-21.

*26. Jackson, D.J. 1937. Host selection in Pimpla examinator F (Hymenoptera) Proc. Roy. Ent. Soc., London, 12(A) : 81-91.

27. Joseph, K.V. 1959. The advisability of spraying DDT on coconut trees over extensive areas in Kerala. First conference of coconut research workers in India, Indian Central Coconut Committee, Ernakulam.

28. Lathrop, F.H. & Newton, R.C. 1933. The biology of Opius melleus Graham, a parasite of the Blueberry maggot. Jour. Agri. Res., 46 : 145-160.

*29. Marchal, P. 1927. Contribution a l etude Ganotypique et phenotypique des Trichogrammes. (Paris) Acad. des. Sci. Compt. Rend., 185 : 489-493.

30. Martin, H., Glenn, L., & Finney. 1946. Control of sex ratio in Macrocentrus ancylivorus. J. econ. Ent., 39 : 296-299.

31. McGugan, B.M. 1955. Certain host-parasite relationship involving the Spruce budworm. Cand. Ent., 87 : 178-187.

*32. Mickel, C.E. 1924. An analysis of a bimodel variation in size of the parasite Dasymutella bioculata. Ent. news., 35 : 236-242

33. Morril, A.W. 1907. Description of a new species of Telenomus with observations on its habits and life history. Amer. Nat., 41 : 417-430.

34. Narayanan, E.S. & Subba Rao, B.R. 1955. Studies on insect parasitism I-iii. Beitrage gur Entomologie, Band 5. N.R. ½.

35. Narayanan, E.S. & Venkataraman, T.V. & Sen Gupta, G.C. 1948. Studies in experimental insect parasitism. Superparasitism. Current Science, 17 : 269-270.

36. Nirula, K.K., Antony, J., Sahasranamam, K., & Menon, K.P.V. 1958. Retentive toxicity of field weathered insecticides to the Eulophid parasite (Trichospilus pupivora F.) associated with Nephantis serinopa M. Indian cocon. J., 11 : 124-132.

37. Oldroyds, H., & Ribbands, C.R. 1936. On the validity of trichiation as a systamatic character in Trichogramm Proc. Roy. Ent. Soc., Lond., B, 5 : 148 :152.

*38. Pantal, J. 1910. Recherches sur les dipteres a larves entomobies. Cellule, 26 : 27-216.

39. Pierce, W.D. & Holloway, T.L. 1912. Notes on the biology of *Chelonus texanus* *J. econ. Ent.*, *5* : 425-428.

40. Proper, A.B. 1931. *Eupteromalus nidulans*, a parasite of the Brown-tail and Satin moths. *Jour. Agr. Res.*, *43* : 37-56.

41. Rakspal, R. 1949. Effect of the sex of the host (*Bagrada cruciferarum*) on the sex of its parasite, *Alophora* sp. (Tachinidae) *Indian J. Ent.*, *16* :80.

42. Ramachandra Rao, Y., Cherian, M.C., & Ananthanarayanan, K.P. 1948. Infestations of *Nephantis serinopa* Meyr. in South India and their control by the biological method. *Indian J. Ent.*, *10* : 205-247.

43. Ramakrishna Ayyar, T.V. & Ananthanarayanan, K.P. 1935. Agricultural Meteorology in its relation to insect pests. *Madras Agric. J.*, *23* : 328-335.

*44. Ratzburg, J.T.C. 1844. Die ichneumon der Forstensecton in Forsthicher und crtomologi. *Beyichunoj*, Berlin, 224 pp..

*45. Roubaud, D.E. 1924. Histaire des *Anacanptomyies mouches* parasites des guepes sociales d' Afrique. *Ann. Sei. nat. Zool.*, *7* : 197-248.

46. Salt, G. 1934. Experimental studies in insect parasitism. I Introduction and Technique. II Superparasitism, *Proc.Roy. Soc., London, Ser.* B., *114* : 450-476.

47. ---- 1935. Experimental studies in insect parasitism. III. Host selection, *Proc. Roy Soc., London, Ser.* B., *117* : 413-435.

48. ---- 1936. Experimental studies in insect parasitism IV. The effect of superparasitism on populations of *Trichogramma evanescens* *Jour. Esp. Biol.*, *13*: 363-375.

49. Salt, G. 1937. The egg parasite of Sialis lutaria : a study of the influence of the host upon a dimorphic parasite. Parasitology, 29 : 539 - 553.

50. ---- 1940. Experimental studies in insect parasitism VII. The effect of different hosts on the parasite Trichogramma evanescens W. Proc. Roy. Ent. Soc. Lond. A, 15 : 81-95.

51. ---- 1941. The effect of hosts upon their insect parasites. Biol. Revs. Cambridge Phil. Soc., 16 : 239-264.

*52. Seyrig, A. 1935. Relations entre le sexe de certains Ichneumonids (Hym.) et. l'hoteaun depens duque itsontvecu. Bull. Soc. ent. Fr., 40 : 67-70.

53. Smith, H.S. 1912. The Chalcid genus Perilampus and its relation to the problem of parasite introduction. Tech. Ser. U.S. Bur. Ent., 19 : 33-69.

54. Strickland, E.H. 1912. The Pezomachini of North America. Ann. ent. Soc. Amer., 5 : 113-140.

55. Taylor, T.H.C. 1937. The biological control of an insect in Fiji. London. 239 pp..

*56. Thompson, W.R. 1923. Sur le determinisme de L'opterisme chez un Ichneumonidae parasite. Soc. Ent. de France, Bull. 40-42.

57. Thompson, W.R. & Parker, H.L. 1927. The problem of host relation with special reference to entomophagous parasites. Parasitology, 19 : 1-34.

58. ----- 1928. The European Corn borer and its controlling factors in Europe. Tech. Bull. U.S. Dep. Agri., 59 : 62 pp..

59. Thorpe, N.H., & Jones, F.G.W. 1937. Olfactory conditioning in a parasitic insect and its relation to the problem of host selection. Proc. Roy. Soc. London, Ser. B, 124 : 56-81.

60. Tothill, J.D., Taylor, T.H.C., & Paine, R.W. 1930. The coconut moth in Fiji. London, 269 pp..

*61. Toyama, K. 1906. Contribution to the study of silk worms. III. On the parasitic fly of the domesticated silk worms of Siam. Bull. Coll. Agri. Toky, 7 : 247-257.

62. Ullyett, G.C. 1936. Host selection by Microplectron fuscipennis Zett. Proc. Roy. Ent. Soc. Ser. B, 120: 253-291.

*63. Vandel, A. 1932. Le sexe des parasites depend - il du nombre d' individus renfermis dans le meme hote? Soc. Ent. de France. Livre. du centenaire: 245-252.

64. Venkataraman, T.V., Gupta. Sn., & Negi, P.S. 1948. Primary trials in propagation of Bracon (Microbracon) greeni. A. on unnatural hosts. Proc. Ind. Acad. Sci., 27: 93-104.

*65. Voukassovitch, P. 1924. Contribution a le' tude Eudenes (Polychrosis batrana Schiff) ole la Pyralidae la vigne (Oenopthera pilleriana Schiff) et de leurs parasites. Thesis Univ: Jourlouse, 248 pp..

66. Webber, R.T. 1937. Laboratory propagation of Compsilura concinnata Meig.. J. econ. Ent., 30: 144-149.

* Original not seen

APPENDIX I

Table 1

Duration of development of *T. pupivora* in pupa of *P. peponis*

Sl. No.	Weight of pupa in Gms.	Date of exposure.	Date of emergence	Duration of development in days
1	0.311	21--9-1962	7--10-1962	17
2	0.330	23--9-1962	10-10-1962	18
3	0.355	9--10-1962	27-10-1962	19
4	0.355	10-10-1962	29-10-1962	20
5	0.289	10-10-1962	28-10-1962	19
6	0.308	11-10-1962	1--11-1962	22
7	0.286	17-10-1962	7--11-1962	22
8	0.299	17-10-1962	3--11-1962	18
9	0.351	17-10-1962	5--11-1962	20
10	0.316	20-10-1962	9--11-1962	21
Average	0.320			19.6

Table 2

Number of adults produced and sex ratio of *T. pupivora* bred on pupa of *P. peponis*

Sl. No.	Weight of pupa in Gms.	Total number of parasites produced.	Number of males	Number of females	Sex ratio Male : Female
1	0.311	433	16	417	26.06
2	0.330	247	10	237	23.70
3	0.355	270	10	260	26.00
4	0.355	301	8	293	36.63
5	0.289	401	11	390	35.45
6	0.308	316	12	304	25.33
7	0.286	268	9	259	28.75
8	0.299	561	16	545	34.06
9	0.351	480	18	462	25.57
10	0.316	452	12	440	36.67
Average	0.320	372.9			29.822

Table 3

Longevity of adults of *T. pupivora* bred on pupa of *P. peponis*

Sl. No.	Wt. of pupa in Gms	Date of emergence	Number of parasites dead on:- (days after emergence) 1	2	3	4	5	6	7	8	9	Total	Longevity (days)
1	0.311	7--10-1962	4	115	301	13						433	2.74
2	0.330	10-10-1962	0	0	89	69	87	1	1			247	3.98
3	0.355	27-10-1962	0	19	23	98	117	11	2			270	4.31
4	0.355	29-10-1962	0	26	21	59	193	0	1	0	1	301	4.43
5	0.289	28-10-1962	1	9	141	30	134	85	0	0	1	401	4.36
6	0.308	1--11-1962	48	121	36	25	42	29	14	0	1	316	3.13
7	0.286	7--11-1962	23	26	86	38	48	29	10	8		268	3.84
8	0.299	3--11-1962	519	40	1	1						561	1.08
9	0.351	5--11-1962	102	77	206	65	16	8	6			480	2.90
10	0.316	9--11-1962	217	90	79	38	28					452	2.05
Av:	0.320											372.9	3.282

Table 4

Measurements of adults of *T. pupivora* bred on pupa of *P. peponis*

Sl. No.	Weight of pupa in Gms.	Measurements in mm. Length Male	Length Female	Width of head Male	Width of head Female.	Width of thorax Male	Width of thorax Female
1	0.311	1.212	1.293	0.402	0.423	0.354	0.351
2	0.330	1.266	1.278	0.354	0.447	0.348	0.387
3	0.355	1.245	1.344	0.372	0.438	0.315	0.375
4	0.355	1.203	1.338	0.363	0.453	0.345	0.360
5	0.289	1.215	1.251	0.378	0.411	0.339	0.354
6	0.308	1.317	1.236	0.372	0.432	0.342	0.363
7	0.286	1.248	1.350	0.378	0.435	0.330	0.369
8	0.299	1.116	1.164	0.333	0.378	0.291	0.306
9	0.351	1.128	1.269	0.327	0.468	0.303	0.345
10	0.316	1.149	1.203	0.375	0.423	0.336	0.324
Av:	0.320	1.210	1.273	0.365	0.431	0.330	0.353

Table 5

Duration of development of T. pupivora in pupa of M. indica

Sl. No.	Weight of pupa in Gms.	Date of exposure	Date of emergence	Duration of development in days
1	0.070	22-9--1962	8--10-1962	17
2	0.066	22-9--1962	9--10-1962	18
3	0.072	23-9--1962	9--10-1962	17
4	0.070	23-9--1962	10-10-1962	18
5	0.075	23-9--1962	9--10-1962	17
6	0.066	24-9--1962	10-10-1962	17
7	0.065	24-9--1962	10-10-1962	17
8	0.068	24-9--1962	10-10-1962	17
9	0.073	28-9--1962	14-10-1962	17
10	0.073	28-9--1962	15-10-1962	18
Av:	0.070			17.3

Table 6

Number of adults produced and sex ratio of T. pupivora bred on pupa of M. indica

Sl. No.	Weight of pupa in Gms	Total number of parasites produced	Number of males	Number of females	Sex ratio Male:Female
1	0.070	121	6	115	19.11
2	0.066	134	9	125	13.89
3	0.072	140	8	132	16.50
4	0.070	158	14	144	10.29
5	0.075	244	22	222	10.55
6	0.066	145	13	132	10.15
7	0.065	183	15	168	11.60
8	0.068	232	14	218	15.57
9	0.073	147	10	137	13.70
10	0.073	133	8	125	15.63
Av:	0.070	163.7			13.699

Table 7

Longevity of adults of *T. pupivora* bred on pupa of *M. indica*

Sl. No.	Wt. of pupa in Gms	Date of emergence	Number of parasites dead on:-(days after emergence) 1	2	3	4	5	6	Total	Longevity (days)
1	0.070	8--10-1962	35	83	3				121	1.77
2	0.066	9--10-1962	5	16	101	11	1		134	2.90
3	0.072	9--10-1962	6	92	39	3			140	2.28
4	0.070	10-10-1962	23	25	99	11			158	2.99
5	0.075	9--10-1962	20	146	59	19			244	2.32
6	0.066	10-10-1962	102	43					145	1.27
7	0.065	10-10-1962	101	79	3				183	1.46
8	0.068	10-10-1962	196	33					232	1.15
9	0.073	14-10-1962	8	111	26	2			147	2.15
10	0.073	15-10-1962	6	4	13	26	62	22	133	4.69
Av.	0.070								163.7	2.298

Table 8

Measurements of adults of *T. pupivora* bred on pupa of *M. indica*

Sl. No.	Weight of pupa in Gms.	Measurements in mm. Length Male	Length Female	Width of head Male	Width of head Female	Width of thor Male	Width of thor Female
1	0.070	1.170	1.227	0.339	0.366	0.360	0.390
2	0.066	0.939	0.912	0.285	0.279	0.252	0.258
3	0.072	1.185	1.212	0.357	0.408	0.321	0.369
4	0.070	1.173	1.194	0.342	0.387	0.318	0.324
5	0.075	1.188	1.137	0.366	0.390	0.339	0.333
6	0.066	1.122	1.068	0.327	0.372	0.309	0.306
7	0.065	1.125	1.137	0.336	0.405	0.303	0.324
8	0.068	1.050	1.095	0.330	0.381	0.297	0.309
9	0.073	1.140	1.167	0.369	0.411	0.321	0.336
10	0.073	1.275	1.224	0.380	0.393	0.360	0.384
Av:	0.070	1.137	1.137	0.343	0.379	0.318	0.333

Table 9

Duration of development of T. pupivora in pupa of L. boeticus

Sl. No.	Weight of pupa in Gms.	Date of exposure	Date of emergence	Duration of development in days.
1	0.103	24--9-1962	10-10-1962	17
2	0.069	25--9-1962	11-10-1962	17
3	0.092	25--9-1962	11-10-1962	17
4	0.084	25--9-1962	12-10-1962	18
5	0.079	7--10-1962	28-10-1962	22
6	0.070	7--10-1962	24-10-1962	18
7	0.071	7--10-1962	25-10-1962	19
8	0.082	7--10-1962	26-10-1962	20
9	0.101	8--10-1962	25-10-1962	18
10	0.072	8--10-1962	26-10-1962	19
Av:	0.082			18.5

Table 10

Number of adults produced and sex ratio of T. pupivora bred on pupa of L. boeticus

Sl. No.	Weight of pupa in Gms.	Total number of parasites produced	Number of males	Number of females	Sex ratio male:female
1	0.103	289	19	270	14.74
2	0.069	164	10	154	15.40
3	0.092	177	9	168	18.67
4	0.084	131	7	124	17.71
5	0.079	189	12	177	14.75
6	0.070	169	13	156	12.00
7	0.071	196	13	183	14.08
8	0.082	144	8	136	17.00
9	0.101	298	18	280	15.56
10	0.072	188	12	176	14.67
Av:	0.082	194.5			15.458

Table 11

Longevity of adults of *T. pupivora* bred on pupa of *L. boeticus*

Sl. No.	Wt. of pupa in Gms.	Date of emergence	Number of parasites dead on:-(days after emergence) 1	2	3	4	5	6	Total	Longevity (days)
1	0.103	10-10-1962	52	54	129	51	3		289	2.65
2	0.069	11-10-1962	86	43	32	3			164	1.69
3	0.092	11-10-1962	43	25	71	36	2		177	2.60
4	0.084	12-10-1962	10	15	71	22	9	1	128	3.06
5	0.079	28-10-1962	117	72					189	1.41
6	0.070	24-10-1962	78	42	28	14	7		169	1.99
7	0.071	25-10-1962	86	45	40	21	4		196	2.17
8	0.082	26-10-1962	10	26	68	19	13	8	144	3.16
9	0.101	25-10-1962	56	62	119	48	13		298	2.66
10	0.072	26-10-1962	108	51	29				188	1.53
Av:	0.082								194.5	2.292

Table 12

Measurements of adults of *T. pupivora* bred on pupa of *L. boeticus*

Sl. No.	Weight of pupa in Gms.	Measurements in mm. Length Male	Length Female	Width of head Male	Width of head Female.	Width of thorax Male	Width of thorax Female.
1	0.103	1.008	1.023	0.300	0.360	0.285	0.279
2	0.069	1.038	1.170	0.318	0.411	0.291	0.333
3	0.092	1.098	1.182	0.342	0.426	0.312	0.318
4	0.084	1.206	1.242	0.357	0.423	0.327	0.381
5	0.079	1.104	1.170	0.321	0.378	0.288	0.300
6	0.070	1.047	1.164	0.321	0.399	0.294	0.327
7	0.071	1.038	1.170	0.315	0.420	0.288	0.321
8	0.082	1.194	1.248	0.354	0.426	0.327	0.378
9	0.101	1.020	1.008	0.321	0.357	0.282	0.291
10	0.072	1.125	1.146	0.318	0.378	0.306	0.297
Av:	0.082	1.088	1.152	0.327	0.398	0.300	0.325

Table 13

Duration of development of *T. pupivora* in pupa of *P. litura*

Sl. No.	Weight of pupa in Gms.	Date of exposure	Date of emergence	Duration of development in days
1	0.180	2--10-1962	21-10-1962	20
2	0.169	2--10-1962	20-10-1962	19
3	0.177	3--10-1962	22-10-1962	20
4	0.149	16-10-1962	3--11-1962	19
5	0.208	22-11-1962	9--12-1962	18
6	0.166	22-11-1962	8--12-1962	17
7	0.156	22-11-1962	9--12-1962	18
8	0.172	22-11-1962	9--12-1962	18
9	0.162	23-11-1962	10-12-1962	18
10	0.180	24-11-1962	11-12-1962	18
Av:	0.172			18.5

Table 14

Number of adults produced and sex ratio of *T. pupivora* bred on pupa of *P. litura*

Sl. No.	Weight of pupa in Gms.	Total number of parasites produced	Number of males	Number of females	Sex ratio male:female
1	0.180	233	12	221	18.42
2	0.169	208	11	197	17.91
3	0.177	217	13	204	15.69
4	0.149	201	11	190	17.27
5	0.208	161	8	153	19.11
6	0.166	199	12	187	15.58
7	0.156	191	11	180	16.36
8	0.172	233	13	220	16.92
9	0.162	218	11	207	18.83
10	0.180	229	13	216	16.61
Av:	0.172	209			17.270

Table 15

Longevity of adults of *T. pupivora* bred on pupa of *P. litura*

Wt. of pupa in Gms	Date of emergence	Number of parasites dead on:- (days after emergence) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total	Longe-vity (days)
0.180	21-10-1962	14	67	102	18	26	6											233	3.05
0.169	20-10-1962	22	76	24	26	16	23	12	9									208	3.00
0.177	22-10-1962	20	14	15	17	9	10	32	29	18								217	5.28
0.149	3--11-1962	20	98	19	22	16	5	21										201	3.05
0.208	9--12-1962	6	2	2	2	5	47	56	7	3	3	0	9	0	10	6	3	161	7.36
0.166	8--12-1962	18	12	10	85	9	7	13	27	9	4	3	1	3	5	3		209	4.96
0.156	9--12-1962	18	102	14	20	13	8	16										191	3.15
0.172	9--12-1962	12	67	118	12	20	4											233	2.88
0.162	10-12-1962	20	98	18	25	19	17	21										218	3.28
0.180	11-12-1962	18	20	79	19	4	6	13	29	30	11							229	4.65
0.172																		209	4.066

Table 16

Measurements of adults of T. pupivora bred on pupa of P. litura

Sl. No.	Weight of pupa in Gms.	Measurements in mm. Length male	Length female	Width of head male	Width of head female	With of thorax male	With of thorax female.
1	0.180	1.098	1.143	0.318	0.357	0.294	0.309
2	0.169	1.104	1.146	0.312	0.354	0.300	0.303
3	0.177	1.110	1.221	0.336	0.432	0.276	0.357
4	0.149	1.113	1.164	0.312	0.375	0.300	0.300
5	0.208	1.350	1.398	0.396	0.471	0.366	0.360
6	0.166	1.104	1.218	0.315	0.432	0.270	0.327
7	0.156	1.110	1.167	0.348	0.375	0.300	0.300
8	0.172	1.218	1.227	0.369	0.393	0.333	0.330
9	0.162	1.110	1.146	0.312	0.363	0.303	0.303
10	0.180	1.104	1.218	0.315	0.462	0.273	0.330
Av:	0.172	1.142	1.205	0.333	0.401	0.302	0.322

Table 17

Duration of development of T. pupivora in pupa of S. derogata

Sl. No.	Weight of pupa in Gms.	Date of exposure	Date of emergence	Duration of development in days
1	0.078	24--9-1962	10-10-1962	17
2	0.075	25--9-1962	12-10-1962	18
3	0.085	25--9-1962	11-10-1962	17
4	0.093	12--11-1962	28-11-1962	17
5	0.079	13-11-1962	29-11-1962	17
6	0.096	13-11-1962	29-11-1962	17
7	0.084	14-11-1962	29-11-1962	16
8	0.083	14-11-1962	30-11-1962	17
9	0.100	14-11-1962	30-11-1962	17
10	0.077	14-11-1962	29-11-1962	16
Av:	0.085			16.9

Table 18

Number of adults produced and sex ratio of T. pupivora bred on pupa of S. derogata

Sl. No.	Weight of pupa in Gms.	Total number of parasites produced	Number of males	Number of females	Sex ratio male:female
1	0.078	196	16	180	11.31
2	0.075	119	7	112	16.00
3	0.085	192	10	182	18.20
4	0.093	147	11	136	12.36
5	0.079	146	9	137	15.22
6	0.096	124	7	117	16.71
7	0.084	248	15	233	15.53
8	0.083	103	6	97	15.17
9	0.100	207	11	196	17.83
10	0.077	189	15	174	11.60
Av:	0.085	167.1			14.993

Table 19

Longevity of adults of *T. pupivora* bred on pupa of *S. derogata*

Wt. of pupa in Gms	Date of emergence	No. of parasites dead on (days after emergence) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total	Longevity (days)
0.078	10-10-1962	86	35	59	11	5												196	2.05
0.075	12-10-1962	19	42	49	7	2												119	2.47
0.085	11-10-1962	10	39	57	76	8	1	1										192	3.21
0.093	28-11-1962	10	6	6	15	4	3	0	8	11	14	25	1	15	25	3	1	147	9.14
0.079	29-11-1962	34	68	40	0	2	2											146	2.13
0.096	29-11-1962	0	0	10	1	1	8	6	48	39	9	2						124	7.87
0.084	29-11-1962	8	9	18	12	4	0	7	46	62	32	29	18	3				248	7.81
0.083	30-11-1962	10	11	6	9	3	5	52	7									103	4.88
0.100	30-11-1962	11	81	9	4	7	4	81	10									207	4.46
0.077	29-11-1962	16	33	9	2	2	3	96	15	7	6							189	5.61
0.085																		167	4.963

Table 20

Measurements of adults of *T. pupivora* bred on pupa of *S. derogata*

Sl. No.	Weight of pupa in Gms.	Measurements in mm. Length Male	Length Female	Width of head Male	Width of head Female.	Width of thorax Male	Width of thorax Female
1	0.078	1.068	1.116	0.330	0.387	0.318	0.312
2	0.075	1.179	1.083	0.354	0.384	0.315	0.306
3	0.085	1.194	1.146	0.336	0.405	0.315	0.330
4	0.093	1.182	1.311	0.363	0.420	0.345	0.309
5	0.079	1.179	1.332	0.375	0.426	0.333	0.345
6	0.096	1.254	1.317	0.384	0.453	0.351	0.378
7	0.084	1.122	1.269	0.333	0.399	0.303	0.333
8	0.083	1.026	1.245	0.312	0.423	0.288	0.345
9	0.100	1.224	1.296	0.369	0.426	0.339	0.339
10	0.077	1.230	1.221	0.345	0.390	0.327	0.330
Av:	0.085	1.166	1.234	0.350	0.411	0.323	0.333

Table 21

Duration of development of *T. pupivora* in pupa of *O. exvinacea*

Sl. No.	Weight of pupa in Gms.	Date of exposure	Date of emergence	Duration of development in days
1	0.145	27--9-1962	16-10-1962	20
2	0.099	1--10-1962	18-10-1962	18
3	0.094	1--10-1962	19-10-1962	19
4	0.127	16-10-1962	4--11-1962	20
5	0.117	20-10-1962	7--11-1962	19
6	0.110	11-11-1962	28-11-1962	18
7	0.125	11-11-1962	27-11-1962	17
8	0.124	18-11-1962	6--12-1962	19
9	0.120	23-11-1962	10-12-1962	18
10	0.112	26-11-1962	14-12-1962	19
Av:	0.117			18.7

Table 22

Number of adults produced and sex ratio of *T. pupivora* bred on pupa of *O. exvinacea*

Sl. No.	Weight of pupa in Gms.	Total number of parasites produced	Number of males	Number of feamles	Sex ratio male:female
1	0.145	135	6	129	21.50
2	0.099	196	10	86	18.60
3	0.094	247	13	234	18.00
4	0.127	337	19	318	16.74
5	0.117	351	18	333	18.39
6	0.110	171	12	159	13.25
7	0.125	256	15	241	16.07
8	0.124	160	7	153	21.86
9	0.120	274	12	262	21.83
10	0.112	227	16	211	13.19
Av:	0.117	235.4			17.943

Table 23

Longevity of adults of *T. pupivora* bred on pupa of *O.exvinacea*

Sl. No.	Wt. of pupa in Gms	Date of emergence	No. of parasites dead on:- (days after emergence) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total	Longevity (days)
1	0.145	16-10-1962	5	42	84	4												135	2.64
2	0.099	18-10-1962	19	173	4													196	1.92
3	0.094	19-10-1962	10	129	77	31												247	2.52
4	0.127	4--11-1962	0	7	12	8	6	71	89	142	2							337	6.87
5	0.117	7--11-1962	9	6	16	38	30	92	103	57								351	5.39
6	0.110	28-11-1962	2	8	14	13	0	6	3	26	40	48	7	4				171	7.85
7	0.125	27-11-1962	17	8	5	5	51	91	25	16	39							256	5.95
8	0.124	6--12-1962	0	3	5	2	10	10	2	3	5	8	59	34	4	7	8	160	9.61
9	0.120	10-12-1962	10	51	95	28	40	50										274	3.64
10	0.112	14-12-1962	44	104	66	10	1	2										227	2.35
Av:	0.117																	235.4	4.874

Table 24

Measurements of adults of *T. pupivora* bred on pupa of *O. exvinacea*

Sl. No.	Weight of pupa in Gms.	Measurements in mm.					
		Length		Width of head		Width of thorax	
		male	female	male	female.	male	female.
1	0.145	1.260	1.311	0.387	0.459	0.354	0.381
2	0.099	1.104	1.239	0.363	0.432	0.315	0.360
3	0.094	1.071	1.888	0.339	0;354	0.297	0.318
4	0.127	1.143	1.212	0.354	0.399	0.342	0.360
5	0.117	1.134	1.173	0.360	0.420	0.339	0.354
6	0.110	1.257	1.272	0.357	0.429	0.330	0 .357
7	0.125	1.122	1.218	0.360	0.393	0.303	0.318
8	0.124	1.233	1.350	0.369	0.444	0.333	0.366
9	0.120	1.185	1.296	0.351	0.417	0.315	0.327
10	0.112	1.050	1.083	0.354	0.381	0.306	0.306
Av:	0.117	1.156	1.234	0.359	0.413	0.323	0.345

Table 25

Duration of Development of *T. pupivora* in pupa of *N. serinopa*

Sl. No.	Weight of pupa in Gms.	Date of exposure	Date of emergence	Duration of development in days.
1	0.076	22-11-1962	10-12-1962	19
2	0.070	22-11-1962	8--12-1962	17
3	0.080	23-11-1962	9--12-1962	17
4	0.058	24-11-1962	10-12-1962	17
5	0.070	24-11-1962	10-12-1962	17
6	0.058	25-11-1962	11-12-1962	17
7	0.060	25-11-1962	12-12-1962	18
8	0.060	25-11-1962	11-12-1962	17
9	0.059	25-11-1962	11-12-1962	17
10	0.064	26-11-1962	12-12-1962	17
Av:	0.066			17.3

Table 26

Number of adults produced and sex ratio of *T. pupivora* bred on pupa of *N. serinopa*

Sl. No.	Weight of pupa in Gms.	Total number of parasites produced	Number of males	Number of females	Sex ratio male:female
1	0.076	148	14	134	9.57
2	0.070	237	18	219	12.17
3	0.080	286	21	265	12.62
4	0.058	244	15	229	15.27
5	0.070	237	16	221	13.75
6	0.058	254	18	236	13.11
7	0.060	141	9	132	14.67
8	0.060	230	14	216	15.43
9	0.059	247	19	228	12.00
10	0.064	253	23	230	10.00
Av:	0.066	227.7			12.859

Table 27

Longevity of adults of *T. pupivora* bred on pupa of *N. serinopa*

Sl. No.	Wt. of pupa in Gms	Date of emergence	Number of parasites dead on:-(days after emergence) 1	2	3	4	5	6	7	8	9	10	11	12	Total	Longevity (days)
1	0.076	10-12-1962	3	36	16	9	36	44	4						148	4.26
2	0.070	8--12-1962	9	9	15	16	90	77	10	11					237	5.09
3	0.080	9--12-1962	0	9	58	29	12	68	73	24	8	2	1	2	286	5.62
4	0.058	10-12-1962	10	25	4	0	72	103	10	4	3	0	12	1	244	4.99
5	0.070	10-12-1962	1	40	94	13	26	57	6						237	3.92
6	0.058	11-12-1962	145	80	21	3	5								254	1.57
7	0.060	12-12-1962	7	17	42	75									141	3.28
8	0.060	11-12-1962	4	9	5	56	128	18							230	4.64
9	0.059	11-12-1962	86	115	44	2									247	1.85
10	0.064	12-12-1962	48	83	46	76									253	2.59
Av:	0.066														227.7	3.781

Table 28

Measurements of adults of *T. pupivora* bred on pupa of *N. serinopa*

Sl. No.	Weight of pupa in Gms.	Measurements in mm.					
		Length		Width of head		Width of thorax	
		Male	Female	Male	Female	Male	Female.
1	0.076	1.170	1.218	0.360	0.426	0.330	0.324
2	0.070	1.158	1.239	0.324	0.378	0.303	0.324
3	0.080	1.176	1.167	0.342	0.402	0.321	0.312
4	0.058	1.053	1.140	0.330	0.393	0.291	0.306
5	0.070	1.041	1.125	0.306	0.378	0.270	0.294
6	0.058	1.083	1.179	0.345	0.381	0.300	0.312
7	0.060	1.191	1.239	0.366	0.387	0.321	0.336
8	0.060	1.149	1.164	0.333	0.390	0.315	0.303
9	0.059	1.080	1.194	0.315	0.381	0.294	0.306
10	0.064	1.107	1.146	0.342	0.393	0.297	0.309
Av:	0.066	1.121	1.181	0.336	0.391	0.304	0.313

Table 29

Duration of development of *T. pupivora* in pupa of *G. soyella*

Sl. No.	Weight of pupa in Gms.	Date of exposure	Date of emergence	Duration of development in days
1	0.003	28--1-1963	13--2-1963	17
2	0.003	28--1-1963	13--2-1963	17
3	0.003	28--1-1963	13--2-1963	17
4	0.005	28--1-1963	13--2-1963	17
5	0.004	28--1-1963	14--2-1963	18
6	0.004	31--1-1963	16--2-1963	17
7	0.004	31--1-1963	16--2-1963	17
8	0.004	31--1-1963	16--2-1963	17
9	0.004	31--1-1963	15--2-1963	16
10	0.003	31--1-1963	16--2-1963	17
Av:	0.004			17

Table 30

Number of adults produced and sex ratio of *T. pupivora* bred on pupa of *G. soyella*

Sl.	Weight of pupa in Gms.	Total number of parasites produced	Number of males	Number of Females	Sex ratio male:female
1	0.003	14	2	12	6.00
2	0.003	13	1	12	12.00
3	0.003	17	2	15	7.50
4	0.005	12	1	11	11.00
5	0.004	16	1	15	15.00
6	0.004	19	2	17	8.50
7	0.004	16	2	14	7.00
8	0.004	12	2	10	5.00
9	0.004	15	2	13	6.50
10	0.003	13	1	12	12.00
Av:	0.004	14.7			9.050

Table 31

Longevity of adults of *T. pupivora* bred on pupa of *G. soyella*

Sl. No.	Wt. of pupa in Gms.	Date of emergence	Number of parasites dead on:-(days after emergence) 1	2	3	4	Total	Longevity (days)
1	0.003	13--2-1963	14				14	1.00
2	0.003	13--2-1963	1	10	2		13	2.08
3	0.003	13--2-1963	1	16			17	1.94
4	0.005	13--2-1963	12				12	1.00
5	0.004	14--2-1963	8	3	5		16	1.00
6	0.004	16--2-1963	19				19	1.00
7	0.004	16--2-1963	15	1			16	1.06
8	0.004	16--2-1963	2	1	8	1	12	2.67
9	0.004	15--2-1963	3	12			15	1.80
10	0.003	15--2-1963	13				13	1.00
Av:	0.004						14.7	1.455

Table 32

Measurements of adults of *T. pupivora* bred on pupa of *G. soyella*

Sl. No.	Weight of pupa in Gms.	Measurements in mm.					
		Length		Width of head		Width of thorax	
		Male	Female	Male	Female	Male	Female
1	0.003	0.915	1.023	0.270	0.345	0.277	0.360
2	0.003	1.080	1.206	0.315	0.396	0.300	0.330
3	0.003	0.938	1.077	0.300	0.351	0.285	0.300
4	0.005	0.900	0.966	0.255	0.226	0.240	0.288
5	0.004	1.065	1.173	0.330	0.400	0.280	0.300
6	0.004	0.990	1.107	0.308	0.399	0.270	0.290
7	0.004	0.953	1.158	0.308	0.363	0.278	0.300
8	0.004	1.088	1.239	0.338	0.417	0.295	0.348
9	0.004	0.975	1.065	0.308	0.369	0.270	0.288
10	0.003	1.080	1.224	0.345	0.454	0.285	0.390
Av:	0.004	0.998	1.124	0.308	0.372	0.278	0.319

Table 38

Duration of development of *T. pupivora* in pupa of *P. peponis* parasitised by five parasites

Sl. No.	Wt. of pupa in Gms.	Date of exposure	Date of emergence	Duration of development in (days)
1	0.311	18--1-1963	8--2--1963	22
2	0.324	18--1-1963	4--2--1963	18
3	0.288	19--1-1963	4--2--1963	17
4	0.292	19--1-1963	8--2--1963	21
5	0.294	20--1-1963	8--2--1963	20
6	0.300	20--1-1963	8--2--1963	20
7	0.345	20--1-1963	9--2--1963	21
8	0.355	20--1-1963	7--2--1963	19
9	0.318	21--1-1963	9--2--1963	20
10	0.338	21--1-1963	7--2--1963	18
Av:	0.317			19.6

Table 39

Number of adults produced and sex ratio of *T. pupivora* bred on pupa of *P. peponis* parasitised by five parasites

Sl. No.	Wt. of pupa in Gms	Total number of parasites produced	Number of males	Number of females	Sex ratio male:female
1	0.311	308	12	296	24.67
2	0.324	441	15	426	28.40
3	0.288	327	10	317	31.70
4	0.292	278	10	268	26.80
5	0.294	411	13	398	30.61
6	0.300	360	9	351	39.00
7	0.345	324	10	314	31.40
8	0.355	283	11	272	24.73
9	0.318	461	14	447	31.93
10	0.338	266	11	255	23.18
Av:	0.317	345.9			29.242

Table 40

Longevity of adults of T. pupivora bred on pupa of P. peponis

Parasitised by five parasites

Sl. No.	Wt. of pupa in Gms	Date of emergence	Number of parasites dead on:-(days after emergence) 1	2	3	4	5	6	7	8	9	10	Total	Longevity (days)
1	0.311	8--2--1963	52	132	25	18	56	18	11	4	2		308	2.95
2	0.324	4--2--1963	8	102	311	14	6						441	2.79
3	0.288	4--2--1963	12	65	81	15	58	0	4	32	46	14	327	4.81
4	0.292	8--2--1963	25	28	80	42	52	31	18	2			278	3.87
5	0.294	8--2--1963	4	12	121	40	146	81	0	7			411	4.43
6	0.300	8--2--1963	16	82	134	22	42	16	28	0	12	8	360	4.07
7	0.345	9--2--1963	0	40	18	68	172	15	0	11			324	4.46
8	0.355	7--2--1963	2	26	18	92	128	12	5				283	4.32
9	0.318	9--2--1963	202	89	102	36	32						461	2.13
10	0.338	7--2--1963	0	2	68	102	79	9	6				266	4.16
Av:	0.317												3459	3.799

Table 41

Measurements of adults of T. pupivora bred on pupa of P. peponis

parasitised by five parasites

Sl. No.	Wt. of pupa in Gms	Measurements in mm. Length Male	Length female	Width of head male	Width of head female	Width of thorax male	Width of thorax female
1	0.311	1.242	1.308	0.368	0.426	0.338	0.363
2	0.324	1.209	1.293	0.399	0.423	0.354	0.366
3	0.288	1.023	1.206	0.321	0.339	0.285	0.306
4	0.292	1.248	1.350	0.348	0.435	0.360	0.339
5	0.294	1.209	1.254	0.375	0.411	0.336	0.357
6	0.300	1.047	1.206	0.321	0.369	0.291	0.306
7	0.345	1.206	1.338	0.360	0.456	0.342	0.363
8	0.355	1.245	1.335	0.375	0.438	0.324	0.378
9	0.318	1.155	1.212	0.347	0.420	0.321	0.333
10	0.338	1.272	1.281	0.357	0.453	0.345	0.387
Av:	0.317	1.186	1.278	0.357	0.417	0.320	0.350

Table 42

Duration of Development of T. pupivora in pupa of P. peponis parasitised by ten parasites

Sl. No.	Wt. of pupa in Gms.	Date of exposure	Date of emergence	Duration of development in days
1	0.292	18--1-1963	3--2-1963	17
2	0.298	18--1-1963	4--2-1963	18
3	0.294	19--1-1963	5--2-1963	18
4	0.349	19--1-1963	4--2-1963	20
5	0.295	20--1-1963	4--2-1963	16
6	0.358	23--1-1963	8--2-1963	17
7	0.340	23--1-1963	8--2-1963	17
8	0.293	23--1-1963	8--2-1963	17
9	0.291	24--1-1963	10-2-1963	18
10	0.312	25--1-1963	12-2-1963	19
Av:	0.312			17.7

Table 43

Number of adults produced and sex ratio of T. pupivora bred on pupa of P. peponis parasitised by ten parasites

Sl. No.	Wt. of pupa in Gms	Total number of parasites produced	Number of males	Number of females	Sex ratio male:female
1	0.292	437	14	423	30.21
2	0.298	331	10	321	32.10
3	0.294	356	15	341	22.73
4	0.349	526	19	507	26.68
5	0.295	437	15	422	28.13
6	0.358	469	25	444	17.76
7	0.340	338	12	326	27.17
8	0.293	346	11	335	30.45
9	0.291	318	11	307	27.91
10	0.312	529	14	515	36.78
Av:	0.312	408.7			27.992

Table 44

Longevity of adults of T. pupivora bred on pupa of P. peponis parasitised by ten parasites

Sl. No.	Wt. of pupa in Gms	Date of emergence	Number of parasites dead on:-(days after emergence) 1	2	3	4	5	6	7	8	9	10	Total	Longevity (days)
1	0.292	3--2-1963	60	160	36	4	15	38	88	36			437	3.91
2	0.298	4--2-1963	28	5	5	13	92	50	40	69	29		331	5.92
3	0.294	5--2-1963	27	16	21	72	92	32	14	6	50	26	356	5.39
4	0.349	4--2-1963	112	88	199	78	22	18	9				526	2.81
5	0.295	4--2-1963	2	71	56	35	104	58	91	16	4		437	5.10
6	0.358	8--2-1963	157	28	6	95	36	28	44	63	12		469	3.79
7	0.340	8--2-1963	33	15	8	67	24	68	62	38	16	7	338	5.43
8	0.293	8--2-1963	27	20	25	72	102	36	48	10	6		346	4.70
9	0.291	10-2-1963	14	68	90	25	42	--	28	49	2		318	4.20
10	0.312	12-2-1963	429	80	10	2	8						529	1.30
Av:	0.312												408.7	4.255

Table 45

Measurements of adults of T. pupivora bred on pupa of P. peponis parasitised by ten parasites

Sl. No.	Wt. of pupa in Gms	Measurements in mm. Length Male	Length female	Width of head male	Width of head female	Width of thorax male	Width of thorax female
1	0.292	1.082	1.082	0.336	0.378	0.306	0.330
2	0.298	1.113	1.182	0.351	0.381	0.312	0.279
3	0.294	1.161	1.215	0.369	0.420	0.348	0.318
4	0.349	1.280	1.281	0.330	0.453	0.315	0.348
5	0.295	1.101	1.188	0.327	0.378	0.303	0.303
6	0.358	1.086	1.137	0.330	0.375	0.303	0.300
7	0.340	1.077	1.140	0.315	0.375	0.303	0.294
8	0.293	1.161	1.212	0.369	0.405	0.348	0.318
9	0.291	1.029	1.206	0.321	0.369	0.285	0.306
10	0.312	1.119	1.128	0.336	0.378	0.306	0.330
Av:	0.311	1.121	1.177	0.338	0.392	0.312	0.311

Table 46

Duration of development of *T. pupivora* in pupa of *P. peponis* parasitised by fifteen parasites

Sl. No.	Wt. of pupa in Gms.	Date of exposure	Date of emergence	Duration of development in days
1	0.305	19--1-1963	5--2--1963	18
2	0.300	19--1-1963	4--2--1963	17
3	0.288	20--1-1963	5--2--1963	17
4	0.307	20--1-1963	5--2--1963	17
5	0.293	23--1-1963	8--2--1963	17
6	0.305	23--1-1963	8--2--1963	17
7	0.298	23--1-1963	8--2--1963	17
8	0.286	24--1-1963	9--2--1963	17
9	0.286	26--1-1963	12-2--1963	18
10	0.302	26--1-1963	12-2--1963	18
Av:	0.297			17.3

Table 47

Number of adult parasites produced and sex ratio of *T. pupivora* bred on pupa of *P. peponis* parasitised by fifteen parasites

Sl. No.	Wt. of pupa in Gms	Total number of parasites produced	Number of males	Number of females	Sex ratio male:female
1	0.305	442	13	429	33.00
2	0.300	528	29	499	17.21
3	0.288	440	12	428	35.67
4	0.307	443	26	417	16.04
5	0.293	463	23	440	19.13
6	0.305	401	24	377	15.71
7.	0.298	474	26	448	17.15
8	0.286	418	11	407	37.00
9	0.286	453	14	439	31.36
10	0.302	476	11	465	42.27
Av:	0.297	453.8			26.454

Table 48

Longevity of adults of *T. pupivora* bred on pupa of *P. peponis* parasitised by fifteen parasites

Sl. No.	Wt. of pupa in Gms	Date of emergence	Number of parasites dead on:-(days after emergence) 1	2	3	4	5	6	7	8	9	10	Total	Longevity (days)
1	0.305	5--2--1963	55	49	28	69	72	49	120				442	4.54
2	0.300	4--2--1963	102	68	92	52	105	64	32	13			528	3.71
3	0.288	5--2--1963	118	13	13	17	28	66	91	49	40	15	450	4.95
4	0.307	5--2--1963	87	7	13	120	96	108	8	4			443	4.14
5	0.293	8--2--1963	92	17	10	99	96	128	21				463	4.18
6	0.305	8--2--1963	24	25	12	53	87	18	182				401	5.03
7	0.298	8--2--1963	24	16	28	40	62	48	198	58			474	5.80
8	0.286	9--2-19 63	47	8	10	30	77	89	115	32			418	5.25
9	0.286	12-2--1963	65	29	28	71	69	142	49				453	4.46
10	0.302	12-2--1963	53	16	28	10	92	102	89	68	18		476	5.46
Av:	0.297												454.8	4.752

Table 49

Measurements of adults of *T. pupivora* bred on pupa of *P. peponis* parasitised by fifteen parasites

Sl. No.	Wt. of pupa in Gms	Measurements in mm. Length Male	Length female	Width of head male	Width of head female	Width of thorax male	Width of thorax female.
1	0.305	1.056	1.206	0.294	0.390	0.291	0.297
2	0.300	1.055	1.077	0.318	0.369	0.294	0.294
3	0.288	1.101	1.206	0.327	0.381	0.297	0.315
4	0.307	1.074	1.197	0.327	0.375	0.300	0.297
5	0.293	1.074	1.191	0.327	0.375	0.300	0.315
6	0.305	1.137	1.140	0.345	0.384	0.333	0.309
7	0.298	1.149	1.218	0.303	0.423	0.300	0.336
8	0.286	1.152	1.179	0.342	0.420	0.300	0.327
9	0.286	1.056	1.092	0.330	0.372	0.294	0.303
10	0.302	1.143	1.212	0.342	0.420	0.303	0.327
Av:	0.297	1.110	1.172	0.336	0.391	0.301	0.312

Table 50

Duration of development of *T. pupivora* in pupa of *P. peponis* parasitised by twenty parasites

Sl. No.	Wt. of pupa in Gms.	Date of exposure	Date of emergence	Duration of development in days
1	0.315	20--1-1963	5--2--1963	17
2	0.328	20--1-1963	5--2--1963	17
3	0.228	20--1-1963	6--2--1963	18
4	0.320	23--1-1963	8--2--1963	17
5	0.297	23--1-1963	8--2--1963	17
6	0.310	23--1-1963	8--2--1963	17
7	0.312	25--1-1963	10-2--1963	17
8	0.300	27--1-1963	12-2--1963	17
9	0.310	27--1-1963	12-2--1963	17
10	0.331	28--1-1963	13-2--1963	17
Av:	0.305			17.1

Table 51

Number of adults produced and sex ratio of *T. pupivora* bred on pupa of *P. peponis* parasitised by twenty parasites

Sl. No.	Wt. of pupa in Gms	Total number of parasites produced	Number of males	Number of females	Sex ratio male:female
1	0.315	643	44	599	13.61
2	0.328	967	40	927	23.18
3	0.228	709	55	654	11.89
4	0.320	746	32	714	22.31
5	0.297	612	40	572	14.30
6	0.310	683	48	635	13.23
7	0.312	657	63	594	9.43
8	0.300	637	44	593	13.48
9	0.310	873	41	832	20.29
10	0.331	901	61	840	13.77
Av:	0.305	742.8			15.49

Table 52

Longevity of adults of *T. pupivora* bred on pupa of *P. peponis* parasitised by twenty parasites

Sl. No.	Wt. of pupa in Gms	Date of emergence	Number of parasites dead on:-(days after emergence) 1	2	3	4	5	6	7	8	Total	Longevity (days)
1	0.315	5--2--1963	225	104	81	21	58	92	48	14	643	3.19
2	0.328	5--2--1963	86	70	24	16	26	33	302	410	967	6.29
3	0.228	6--2--1963	238	128	60	82	102	42	48	9	709	3.06
4	0.320	8--2--1963	170	48	44	255	229				746	3.43
5	0.297	8--2--1963	92	162	138	220					612	2.79
6	0.310	8--2--1963	259	150	49	150	48	19	8		683	2.54
7	0.312	10-2--1963	263	153	42	155	20	15	9		657	2.39
8	0.300	12-2--1963	294	62	82	23	72	96	8		637	2.74
9	0.310	12-2--1963	484	176	82	68	26	28	9		873	1.96
10	0.331	13-2--1963	96	189	211	405					901	3.03
Av:	0.305										742.8	3.142

Table 53

Measurements of adults of *T. pupivora* bred on pupa of *P. peponis* parasitised by twenty parasites

Sl. No.	Wt. of pupa in Gms	Measurements in mm. Length Male	Length female	Width of head male	Width of head female	Width of thorax male	Width of thorax female
1	0.315	1.068	1.104	0.318	0.363	0.306	0.360
2.	0.328	1.023	1.143	0.318	0.387	0.288	0.321
3	0.228	1.074	1.095	0.305	0.372	0.303	0.291
4	0.320	1.074	1.098	0.318	0.363	0.270	0.288
5	0.297	0.999	1.020	0.306	0.351	0.270	0.312
6	0.310	0.987	1.053	0.285	0.342	0.273	0.291
7	0.312	0.987	1.053	0.285	0.342	0.264	0.290
8	0.300	1.068	1.104	0.327	0.357	0.306	0.291
9	0.310	1.026	1.056	0.318	0.351	0.285	0.300
10	0.331	1.059	1.076	0.321	0.366	0.276	0.297
Av:	0.305	1.037	1.080	0.310	0.359	0.284	0.304

APPENDIX II

A. Analyses of covariance of different characters of *Trichospilus pupivora* with respect to different species of host pupae.

Design:- Completely randomised design. Tr

Treatments:- 8 species of host pupae.

Replication:- 10

Ancillary variate:- The weight of host pupa.

(a) Number of *T. pupivora* produced

Table of analysis of variance and covariance

Source	S.S.(b^2)	S.P.(ab)	S.S.(a^2)	Adjusted S.S.	d.f.	Variance	F ratio
Total	920880.688	576.643	0.655		78		
Treatment	684176.188	579.576	0.641		7		
Error	236704.500	-2.933	0.041	236089.639	71	3325.206	
Error + treat	920880.688	576.643	0.655	413220.918			
Treat.				177131.279	7	25225.415	7.6*

** Significant at 1% level.

Where a = weight of host pupa   b = Number of parasites produced.

S.S. = sum of squares   S.P. = sum of products.

d.f. = degrees of freedom

Table of number of T. pupivora produced adjusted for weight of host pupae

Treatment number	Mean weight of host pupa.	Mean number of parasites produced	
		Unadjusted	Adjusted
1	0.320	372.9	416.072
3	0.117	235.4	236.029
2	0.172	209.0	221.155
7	0.066	227.7	217.536
5	0.082	194.5	187.794
4	0.085	167.1	161.024
6	0.070	163.7	154.479
8	0.004	14.7	-8.416

Standard error of adjusted mean (S.E.) = 70.811

Critical difference of adjusted mean (C.D) = 141.339.

(b) Sex ratio of T. pupivora

Table of analysis of variance and covariance

Source	$S.S.(O^2)$	S.P.(aO)	$S.S.(a^2)$	Adjusted S.S.	d.f.	Variance.	F ratio
Total	3267.9808	39.7255	0.655		78		
Treatment	2599.9613	39.9264	0.641		7		
Error	668.0195	-0.2009	0.014	665.1365	71	9.368	
Error + treat	3267.9808	39.7255	0.655	858.0988			
treat				192.9623	71	27.566	2.9**

O = Sex ratio of T. pupivora.

Table of sex ratio of *T. pupivora* adjusted for weight of host pupae

Treatment number	Mean weight of host pupa	Mean sex ratio of *T. pupivora*	
		Unadjusted	Adjusted
1	0.320	29.822	32.780
2	0.172	17.270	18.102
3	0.117	17.943	17.986
5	0.082	15.458	15.004
4	0.085	14.993	14.568
6	0.070	13.699	13.061
7	0.060	12.859	12.174
8	0.004	9.050	7.471

S.E. = 1.874   C.D. = 7.502

(c) Developmental period of *T. pupivora*

Table of analysis of variance and covariance

Source	S.S.(k^2)	S.P.(ak)	S.S.(a^2)	Adjusted S.S.	d.f.	Variance	F ratio
Total	143.95	5.501	0.655		78		
Treatment	67.35	5.522	0.641		7		
Error	76.60	-0.021	0.014	76.569	71	1.078	
Error + treat.	143.95	5.501	0.655	97.750			
Treat				21.181	7	3.026	2.8**

k = Developmental period

Table of developmental period of T. pupivora adjusted for weight of host pupa

Treatment number	Mean weight of host pupa	Mean developmental period of T. pupivora	
		Unadjusted	Adjusted
1	0.320	19.6	19.909
3	0.117	18.7	18.704
2	0.172	18.5	18.587
5	0.082	18.5	18.452
6	0.070	17.3	17.239
7	0.066	17.3	17.228
4	0.082	16.9	16.852
8	0.082	17.0	16.835

S.E. = 1.272 C.D. = 2.539

(d) Longevity of T. pupivora

Table of analysis of variance and covariance

Source	S.S.(l^2)	S.P.(al)	S.S.(a^2)	adjusted S.S.	d.f.	Variance	F ratio
Total	304.033	3.1008	0.655		78		
Treatment	114.389	2.9621	0.641		7		
Error	189.644	0.1387	0.014	188.268	71	2.652	
Error + Treat.	304.033	3.1008	0.655	289.352			
Treat.				101.084	7	14.445	5.4**

l = Longevity of T. pupivora.

Table of longevity of T. pupivora adjusted for weight of host pupa

Treatment number	Mean Weight of host pupa	Mean longevity of T. pupivora	
		Unadjusted	Adjusted
4	0.085	4.963	5.250
3	0.117	4.874	4.844
7	0.066	3.781	4.247
2	0.172	4.066	3.491
6	0.070	2.298	2.724
5	0.082	2.292	2.609
8	0.004	1.455	2.545
1	0.320	3.282	1.241

S.E. = 2   C.D. = 3.992

(e) Size of T. pupivora

Table of analysis of variance and covariance

Source	S.S.(h^2)	S.P.(ah)	S.S.(a^2)	Adjusted S.S.	d.f.	Variance.	F ratio
Total	0.120531	0.117816	0.655		78		
Treatment	0.025446	0.106609	0.641		7		
Error	0.095085	0.011207	0.014	0.086	71	0.0012	
Error + treat.	0.120531	0.117816	0.655	0.099			
Treat.				0.013	7	0.0018	1.5

F ratio not significant.

B. Analyses of covariance of different characters of *Trichospilus pupivora* bred on pupa of *Phytometra peponis* with respect to different levels of induced superparasitism.

Design:- Completely randomised design.

Treatments:- 4 levels of induced superparasitism (i.e. the number of parasites parasitising the pupa).

Replication:- 10.

Ancillary variate:- The weight of host pupa.

(f) Number of *T. pupivora* produced

Table of analysis of variance and covariance

Source	S.S.(b^2)	S.P.(ab)	S.S.(a^2)	Adjusted S.S.	d.f.	Variance	F ratio
Total	1181861.9	-0.7124	0.02175		38		
Treatment	925061.8	-19.1457	0.00218		3		
Error	256800.1	18.4333	0.01956	239470.3	35	6842.0	
Error + treat.	1181861.9	-0.7124	0.02175	1181838.8			
Treat				942368.5	3	314122.9	45.9**

Table of number of *T. pupivora* produced adjusted for weight of host pupae

Treatment number	Mean weight of host pupa	Mean number of parasites produced: Unadjusted	Mean number of parasites produced: Adjusted
20	0.305	742.8	750.338
15	0.297	453.8	464.858
10	0.312	408.7	404.470
5	0.317	345.9	337.628

S.E. = 37.67 C.D. = 76.527

(g) Sex ratio of T. pupivora

Table of analysis of variance and covariance

Source	S.S.(O^2)	S.P.(aO)	S.S.(a^2)	Adjusted S.S.	d.f.	Variance	F ratio
Total	2480.086	-0.2758	0.02175		38		
Treat.	1182.366	+0.5981	0.00218		3		
Error	1297.720	-0.8739	0.01956	1257.676	35	35.933	
Error + treat.	2480.086	-0.2758	0.02175	2476.588			**
Treat				1218.912	3	406.304	11.307

Table for sex ratio of T. pupivora adjusted for weight of host pupa

Treatment number	Mean weight of host pupa	Mean sex ratio of T. pupivora	
		Unadjusted	Adjusted
5	0.317	29.242	29.680
10	0.312	27.992	28.216
15	0.297	26.454	25.921
20	0.30 5	15.549	15.420

S.E. = 2.73 C.D. = 5.546

(h) Developmental period of T. pupivora

Table of analysis of variance and covariance

Source	S.S.(k^2)	S.P.(ak)	S.S.(a^2)	Adjusted S.S.	d.f.	Variance	F ratio
Total	76.775	0.2061	0.02175		38		
Treatment	39.275	0.2256	0.00218		3		
Error	37.500	-0.0195	0.01957	37.483	35	1.0709	
Error + treat.	76.775	0.2061	0.02175	74.824			**
Treat.				37.341	3	12.447	11.62

Table for developmental period of *T. pupivora* adjusted for weight of host pupa

Treatment number	Mean weight of host pupa	Mean developmental period of *T. pupivora*	
		Unadjusted	Adjusted
5	0.317	19.6	19.609
10	0.312	17.7	17.704
15	0.297	17.3	17.289
20	0.305	17.1	17.097

S.E = 0.471   C.D = 0.957

(i) Longevity of *T. pupivora*

Table of analysis of variance and covariance

Source	S.S.(1^2)	S.P.(al)	(S.S.(a^2)	Adjusted S.S.	d.f.	Variance	F ratio
Total	61.784	-0.1514	0.02175		38		
Treat.	17.061	-0.0836	0.00218		3		
Error	44.723	-0.0678	0.01957	44.489	35	1.271	
Error + treat.	61.784	-0.1514	0.02175	60.731			**
Treat.				16.242	3	5.418	4.26

Table of longevity of *T. pupivora* adjusted for weight of host Pupa

Treatment number	Mean weight of host pupa	Mean longevity of *T. pupivora*	
		Unadjusted	Adjusted
15	0.297	4.932	4.895
10	0.312	4.255	4.270
5	0.317	3.799	3.829
20	0.305	3.142	3.133

S.E. = 0.512   C.D. = 1.040

(j) Size of *T. pupivora*

Table of Analysis of variance and covariance

Source	S.S.(h^2)	S.P.(ah)	S.S.(a^2)	Adjusted S.S.	d.f.	Variance	F ratio
Total	0.04118	0.0096	0.02175		38		
Treat.	0.01668	0.0031	0.00218		3		
Error	0.02450	0.0065	0.01967	0.0223	35	0.00064	
Error + treat.	0.04118	0.0096	0.02175	0.0370			
Treat				0.0147	3	0.00490	7.2**

Table for size of *T. pupivora* adjusted for weight of host pupa

Treatment number	Mean weight of host pupa	Mean size of *T. pupivora*	
		Unadjusted	Adjusted
5	0.317	0.4170	0.4141
15	0.297	0.3910	0.3945
10	0.312	0.3920	0.3901
20	0.305	0.3590	0.3609

S.E. = 0.01155 C.D. = 0.0235

PLATES

PLATE 1

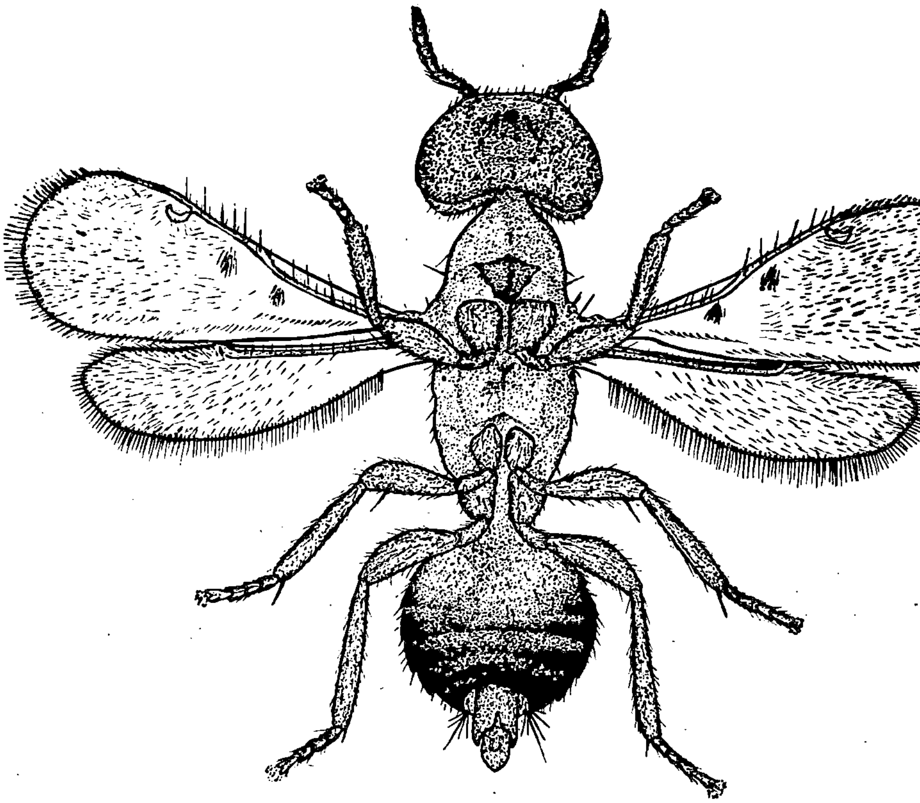
PLATE 1

Trichospilus pupivora F.

Ventral view of adult male and female

VENTRAL VIEW OF TRICHOSPILUS PUPIVORA

MALE



FEMALE

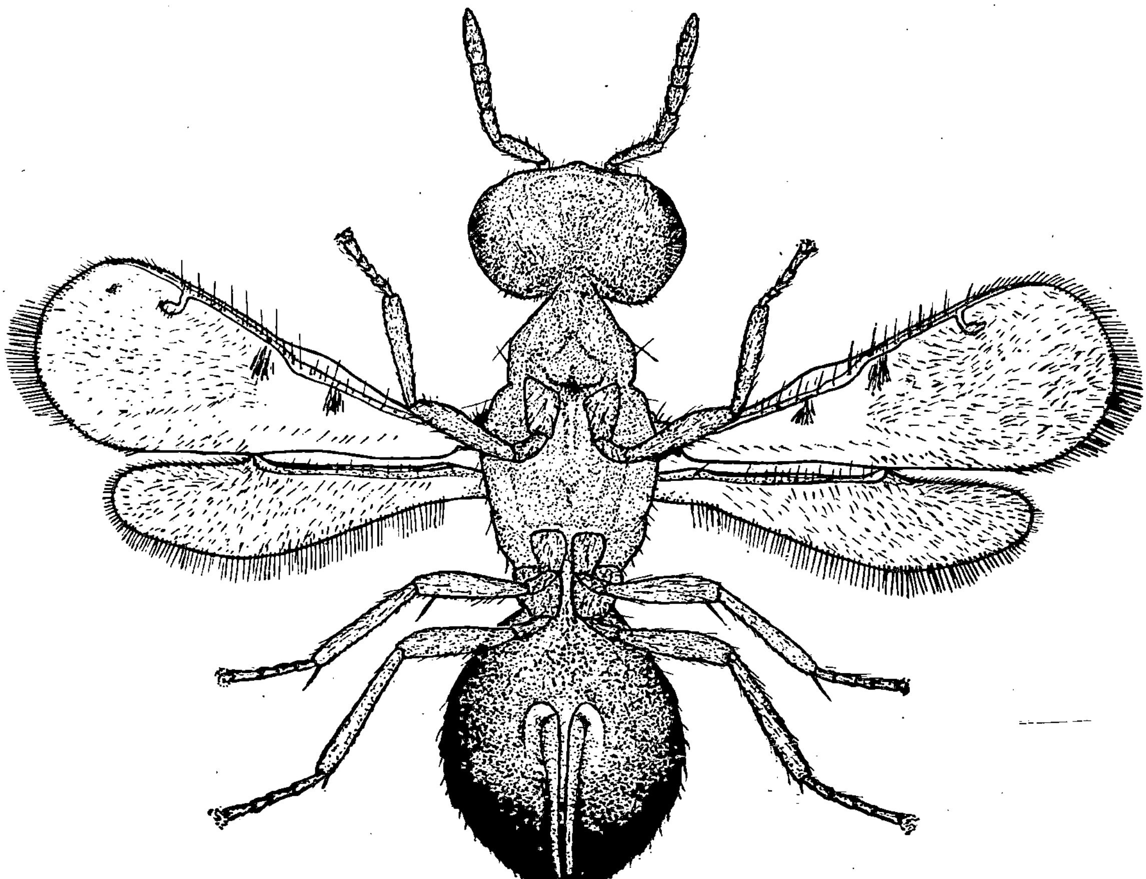
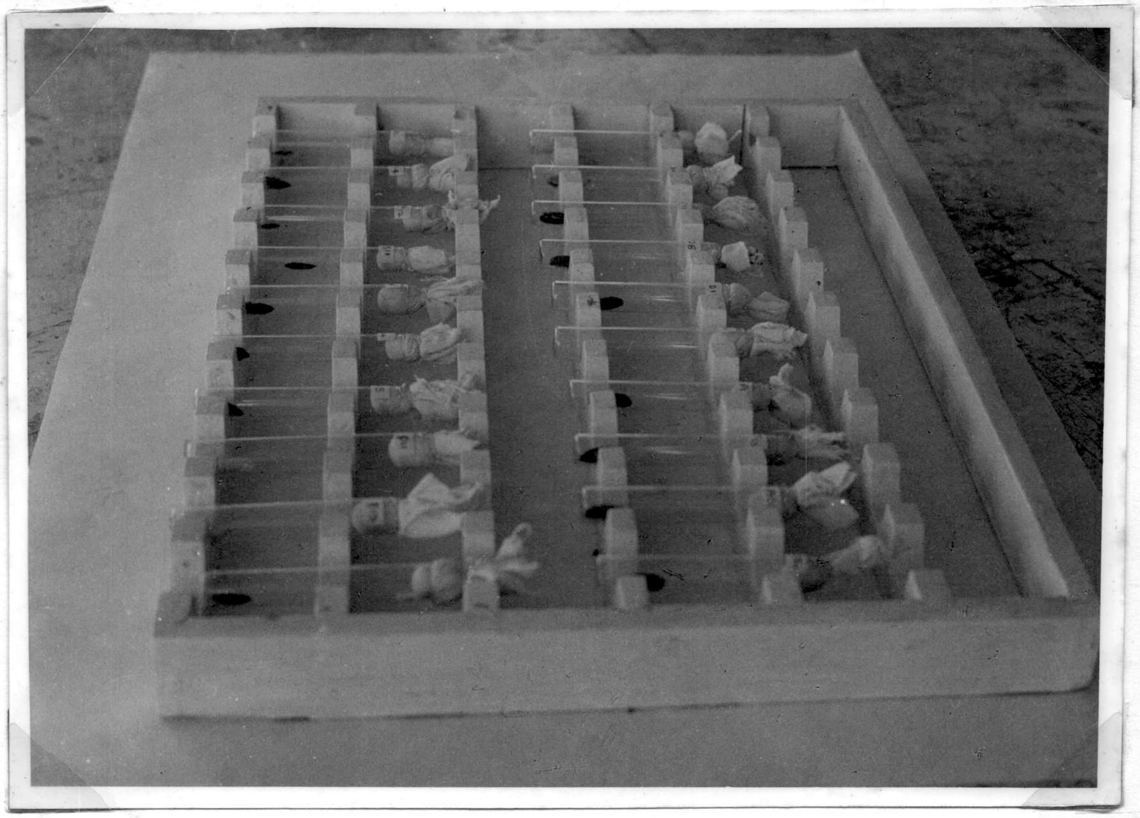


PLATE 2

PLATE 2

a. Host pupae set for parasitisation by *T. pupivora*.

b. Rearing tubes with parasitised host pupae within, on tube stand.



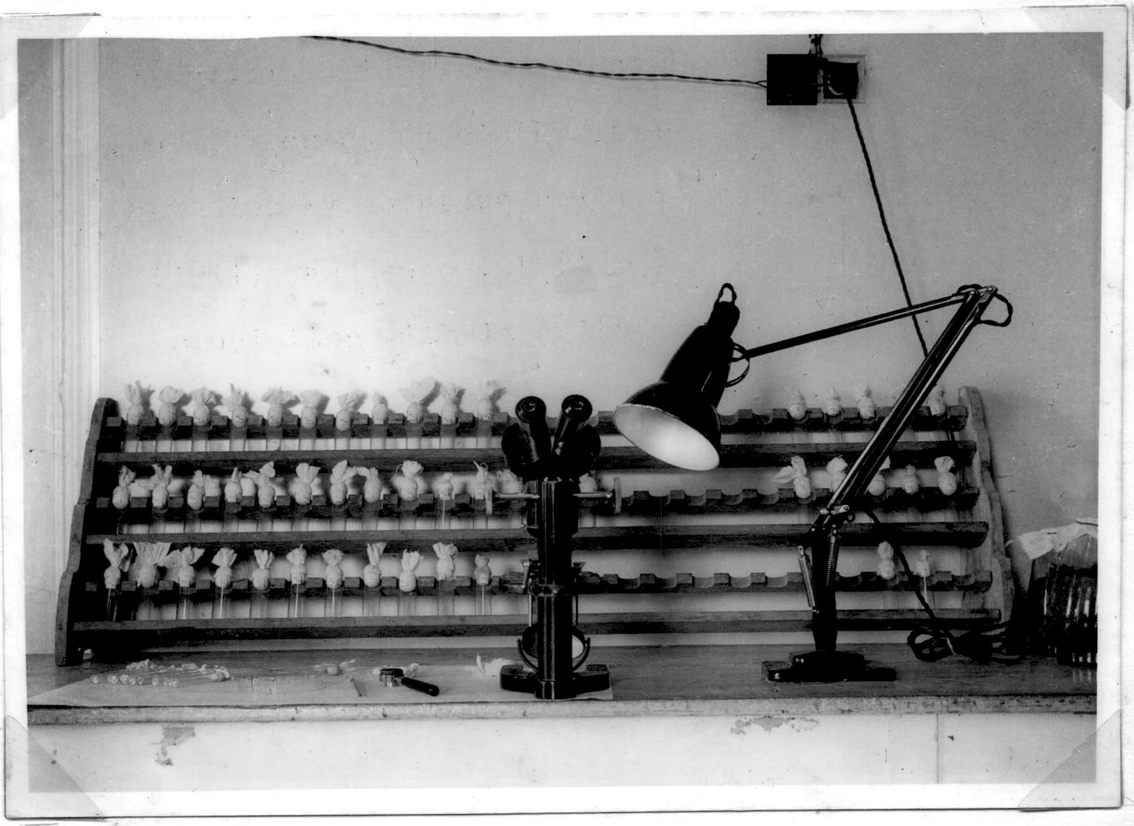


PLATE 3

PLATE 3

Showing method of removing dead parasites from the rearing tubes.