Name: Sharon Clairene Young Date of Degree: August 7, 1965

Institution: Oklahoma State University

Location: Stillwater, Oklahoma

Title of Report: LIFE HISTORIES AND REARING TECHNIQUES OF REPRESENTATIVE SPECIES OF THE ORDER THYSANOPTERA

Pages in Report: 27

Candidate for Degree of Master of Science

Major Field: Natural Science

Scope of Study: Information on the biology and life histories of insects in the order Thysanoptera is scattered and usually published as explanatory material in taxonomic and control literature. This paper is an attempt to bring together and compare life history data for representative species. A section on rearing Thysanoptera for study in the laboratory is also included.

Findings and Conclusions: A great deal of variation in habits and life cycles was found. There are a number of species whose life histories have never been studied. Several basic rearing techniques have been developed which can be adapted to a particular species and research problem.

ADVISER'S APPROVAL William A. Drew

LIFE HISTORIES AND REARING TECHNIQUES OF REPRESENTATIVE SPECIES OF THE ORDER THYSANOPTERA

By

SHARON CLAIRENE YOUNG

Bachelor of Science
Bethany Nazarene College
Bethany, Oklahoma
1964

Submitted to the Faculty of the Graduate School of
the Oklahoma State University
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
August, 1965

LIFE HISTORIES AND REARING TECHNIQUES OF

REPRESENTATIVE SPECIES OF THE

ORDER THYSANOPTERA

Report Approved:

L. Herbert Bunch

William A. Drew

Dean of the Graduate School

PREFACE

Most of the studies done with Thysanoptera are of an economic nature. The recent literature on the group deals primarily with the development of insecticides and control techniques. Literature concerning the biology and life histories of the various species is scattered and, for the most part, published as adjuncts to control studies. It was, therefore, desirable to collect what is known of the life histories of several groups of Thysanoptera into one paper.

Another purpose of this paper is to review some of the methods which have proved successful for rearing these insects in the laboratory and overcoming the difficulties associated with their minute size and unique life history. It is hoped that the material presented here will be useful to myself and others in rearing Thysanoptera in the laboratory.

I wish to express my thanks to Dr. L. Herbert Bruneau and Dr. William A. Drew for their advice and assistance in writing this paper. I also want to express my appreciation to Dr. Douglas E. Bryan and Dr. R. R. Walton for allowing me to use bibliographical references and reprints of literature from their files.

I am indebted to Dr. Robert Fite and the national administrators of the National Science Foundation for providing financial assistance and the opportunity to participate in this master's program.

TABLE OF CONTENTS

CHAPTER I

INTRODUCTION

The members of the order Thysanoptera are minute insects ranging from 1/50 to 1/2 inch in length (Wigglesworth, 1964) (Borror and DeLong, 1964). They are rarely seen or recognized by laymen and the secretive habits and extreme difficulty encountered in rearing them have discouraged many entomologists from working with the order. Were it not for the severe damage to crops caused by some species the group would doubtless be even less well known. The Thysanoptera do, however, present some interesting and diverse life histories and some successful methods for rearing them for study in the laboratory have been developed.

General Characteristics

The Thysanoptera are apparently not closely related to any other insect group (Howard, 1907). Although they have, at various times, been placed in the Hemiptera, Homoptera and Orthoptera they are in many ways unique and belong in a distinct order (Folsom, 1922). Although a few members are apterous the most outstanding characteristic of the group is the presence of four narrow, membranous, usually veinless, wings fringed with long delicate hairs. The mouthparts are also aberrant and cannot be described as true sucking or biting types (Ealand, 1921). The one or two-segmented tarsi are terminated by a

bladder-like structure. Metamorphosis is of a type intermediate between complete and simple and will be described in detail below. Although some recent workers tend to prefer the hemimetabolous terms for the immature instars, the terms "larvae" and "pupae" will be retained in this paper since most of the life histories published use the latter names.

Early History

The history of the study of Thysanoptera began in 1744 when DeGeer described them and gave to them the name Physapus. Linnaeus, however, placed them in the order Hemiptera, genus Thrips. It was not until 1826 that Haliday raised the group to order rank and suggested the name Thysanoptera which refers to the tasseled wings. Linnaeus' genus Thrips still stands and the common name, thrips, is applied to all the members of the order. Since the common name is derived from the generic name Thrips which is masculine singular, it is incorrect to omit the "s" and call an individual a "thrip" (Hinds, 1902).

Classification

The order is divided into two suborders, largely on the basis of the genital apparatus. In the suborder Terebrantia the females have prominent sawlike ovipositors and have the last abdominal segment conical. The terminal abdominal segment of the males is broadly rounded. The females of the suborder Tubulifera have no ovipositors, and the tip of the abdomen is tubular and similar in both sexes (Borror and DeLong, 1964). As might be expected from the morphology of the ovipositors, the Terebrantia pierce the plant tissue and deposit the

eggs singly inside the plant while Tubulifera deposit the eggs in groups or singly on the surface of the leaves and bark (Imms, 1934). Both suborders contain predators and phytophagous species. In general the Terebrantia are quite active and have a wide host range while the Tubulifera are larger, more sluggish, and can reproduce on a limited number of plant species (Bailey, 1935).

The classification of genera and species is in a state of flux. Several species mentioned in the literature are synonymous and others have been placed in different genera. In species where the current taxonomic position is known it will be noted, but since a taxonomic study has not been attempted in this paper, life histories will be described using the names under which they were published.

CHAPTER II

A GENERALIZED BIOLOGY OF THE THYSANOPTERA

The metamorphosis of the Thysanoptera is unique and lies somewhere between the typical simple metamorphosis and true complete metamorphosis. The first two instars are well developed morphologically (Bryan and Smith, 1956), and small compound eyes are present. In addition, they feed and behave in a way very similar to the adults. In these respects they conform to simple hemimetabolous development. However, in species whose wings develop during these stages the wings are internal and thus resemble complete or holometabolous development (Borror and DeLong, 1964). These two instars differ from each other principally in size and are called larvae or nymphs depending on which type of metamorphosis one is inclined to accept. The third instar termed the prepupa or early pseudopupa has external wing pads and is more or less inactive depending on the species. Usually the prepupa does not feed and often seeks out a secluded place to pupate. The appendages are free and the antennae project forward (Imms, 1934). At the end of this short stadium a third molt occurs and the pupa or pseudopupa emerges. It is fairly quiescent though capable of crawling slowly if disturbed. There is a chitinous covering and the antennae are reflexed back over the head and thorax (Imms, 1934). No food is eaten during this stage, the wings continue to develop externally, and in some species a cocoon

is formed (Bailey, 1940b). Except for the type of wing development and the mobility, the pupa resembles the typical pupae occuring in complete metamorphosis. When the adult emerges it usually feeds before mating or ovipositing (Bailey, 1933a).

Mating is promiscuous and the males are very aggressive, fertilizing as many as six females in 15 minutes (Hinds, 1902). Copulation in Tubulifera occurs with the male positioned upon the back of the female and grasping her thorax. The ventral side of his abdomen is placed on the side of the female's abdomen and bent around until the ventral surfaces of the last segments are in apposition. The male genital apparatus is exerted while the female lifts the end of the abdomen to present the sexual opening. Copulation lasts about 30 seconds, after which the stronger female begins to move away dragging the male until he can free himself (Hinds, 1902). Copulation is quite similar in Terebrantia but perhaps the time required is longer. Bailey (1933a) reported that the time varied from two to ten minutes in Hercothrips fasciatus.

Oviposition in the Terebrantia usually occurs in the same plant tissues the adults feed upon. Some authors indicate that feeding is necessary to weaken the epidermis before the ovipositor can pierce it (Moulton, 1907). After the female has selected a site for ovipositing, she lifts the abdomen and extrudes the ovipositor to a position at almost right angles to the body and pierces the epidermis. The abdomen is arched so that the weight is focused upon the ovipositor and the body is rocked back and forth to drive the entire ovipositor into the tissue and enlarge the slit. After a short rest the female grasps the surface with her feet and by contractions of the body the

large bean shaped egg is forced into the plant tissue (Bailey, 1933) (Williams, 1916) (Hinds, 1902).

The feeding of both larvae and adults is done by piercing the surface of plant or animal tissue and sucking the juices. The thrips have a conical beak which projects from the posterior ventral aspect of the head and is formed by the labrum maxillae and labium. Within the mouth cone are three stylets composed of the left mandible and extensions of the maxillae (Snodgrass, 1935). The stylets are protruded from the distal opening of the mouth cone and used to pierce the epidermis and deeper tissues. Then a rooting motion of the head is used to enlarge the opening and cause the juices to flow, after which the stylets are retracted and the mouth cone is immersed in the liquid. Muscles attached to the pharynx dilate it producing a vacuum and the juices are sucked up. The thrips do not have a salivary tube as do some insects and the lubricant produced is not toxic (Bailey, 1935) (Moulton, 1907).

CHAPTER III

LIFE HISTORIES OF VARIOUS SPECIES

As mentioned above no attempt will be made to place the groups discussed in taxonomic order, but the various genera and species will be treated according to biological similarities. Species of both phytophagous and predaceous habits are found within both suborders and even within the same family.

Heliothrips haemorrhoidalis (Bouche), the greenhouse thrips, is among the most widely distributed species of Thysanoptera in the world (Williams, 1918). Its feeding injures the foliage of plants in greenhouses and also out-of-doors in warm climates. The adults begin to feed upon the under surface of leaves soon after emerging from the pupa. They are about .04 inch long and walk rapidly over the leaves. When disturbed they raise the tip of the abdomen and run but can not be induced to fly. Oviposition is typical of the Terebrantia with the female slitting the epidermis and inserting a single egg. The reniform eggs hatch in about eight days and the small white larvae begin to feed gregariously. A red fluid accumulates at the anal openings of the larvae (hence the specific name) and finally drops to the leaf and dries in black spots. Each molt occurs unprotected among the feeding members of the colony. The two larval instars are completed in about 10 to 20 days. The prepupa and pupae are fairly typical of the order. No food is taken and the pupa is almost motionless. The prepupal stage lasts 10-15 hours and the pupal stage 4 to 6

days. The total life cycle requires from 20 to 33 days (Russell, 1909) (Russell, 1912a). Reproduction is parthenogenic and no males are known (Hinds, 1902).

The red-banded thrips, Selenothrips rubrocinctus (Girard) is similar to the greenhouse thrips both in structure and biology and was formerly included within the same genus (Williams, 1918). In the West Indies this same species is called the cacao thrips and is a serious crop pest. The adults feed in the same manner as the greenhouse thrips and the two species are often found together but the red-banded thrips is even more active and can jump and crawl very rapidly. They often carry the abdomen high and curled forward. The female inserts the eggs singly in young foliage and seals the opening with a large scale of excrement. The eggs take 9 to 16 days to hatch and begin to swell near the end of this period unsealing the egg-pocket. The larval period varies from 6 to 20 days depending on the temperature. Like Heliothrips haemorrhoidalis they exude a red liquid from the anus, but the tip of the abdomen is held high in the air. They are also a bit more secretive while molting than the former species, seeking out a folded leaf or spider web. The larval skin splits on the head and by contracting the body the prepupae free themselves from the larval skin. This instar is very inactive, although capable of movement. The pupae are also motionless and the pupae and prepupae lie clustered together during the 3 to 8 days of development. After emerging the adult remains quiet for about a day while the chitin hardens before beginning to feed. In Trinidad the life cycle takes 16 to 18 days, but in Florida may span 20 to 40 or more days. The males of this species are rare and it is probable that bisexual reproduction only occurs during certain parts of

the year (Russell, 1912c).

The bean thrips, Hercothrips fasciatus (Pergande), is closely related to the two previously discussed species, but differs from them in several important aspects: (1) Pupation occurs in the soil, (2) Adults hibernate through the winter, and (3) Reproduction is bisexual and males are necessary to carry on the species. When cold weather approaches in autumn, the adults cease reproductive activities and feeding and seek out a protected place to hibernate. A few find enough protection under leaves and in cracks to survive rain and cold weather. They become active again about the last of March (Bailey, 1933a). The ratio of females to males is about 2:1, but since the males are quite active sexually most females are probably fertilized (Bailey, 1933a). Mating and ovipositing are typical of the Terebrantia. In the cool weather of early spring incubation may last 20 days but in summer lasts only about seven days. The two larval instars which are quite similar to the previously discussed species last about 10 to 20 days. The prepupa drops to the ground and crawls under rubbish or clods of dirt or crawls down into cracks in the ground to pupate (Russell, 1912b). Bailey (1933a) found that the newly emerged adult was not able to dig its way out of the soil. If the ground surface is disturbed and the adult is unable to crawl back out the original opening it dies. He also determined the mortality rate between second instar larvae and adults to be approximately 60 per cent. The young adults rest the first day after emergence, feed the second day and then begin reproductive activities. Reproduction is bisexual with mating necessary to preserve the species. Parthenogenesis can occur, but unfertilized females produce only male offspring (Bailey, 1933a).

Neoheegeria verbasci (Osborn), the mullein thrips, belongs to the suborder Tubulifera, but its biology is in some ways similar to that of the bean thrips. Its method of reproduction is necessarily bisexual (Bailey, 1933a), as is that of the bean thrips. Only males are produced parthenogenetically and mating is necessary to maintain the species (Shull, 1917). Where winters are cold the mullein thrips hibernate. The flower spikes and basal leaves of the mullein plant (Verbascum thapsus L.) afford good protection during hibernation. Unlike Hercothrips fasciatus this species has a very narrow host range and can reproduce only on mullein. Eggs are laid on the flower and leaves and hatch in about 12 days. The larvae feed with the adults on tender shady parts of the plant and the two larval instar are completed in about 28 days, depending on the temperature. There are three pupal instars (one prepupal and two pupal). These take about nine days and occur among the feeding thrips. In warm climates, three generations per year are completed. Hardly any damage is done to the host plant even though large numbers of the thrips feed on it. Mullein is a biennial and the colony of thrips remain on a plant two years before crawling to the young plants which sprout up around it (Bailey, 1939a).

Limnothrips cerealium Haliday, the wheat thrips and L. denticornis Haliday, the barley thrips differ from the mullein thrips in that they have a wider host range and normally migrate infesting two different hosts per year. The adult females hibernate during winter on native grass and feed upon these until the sown cereals begin to head out in June and July (Post and Colberg, 1958) (Lewis, 1959). The eggs are laid in the leaves and leaf sheaths in the manner usual for Terebrantia. The eggs hatch in about five to eleven days and larvae and adults feed

together on the cereal. The two larval stages last about 13 days and the two pupal stages about seven days (also on the host). The total life cycle takes about 29 to 35 days and only one brood is produced per year (Sharga, 1933). However, large populations can build up. Post and Olson (1960) reported 23,958,000 barley thrips per acre in the upper Red River Valley in North Dakota. The second generation females feed on the host until about harvest time and then migrate sometimes in large swarms back to the native grasses where they feed until cold weather before hibernating. The males are apterous and die after mating. The flights are not long (only five to eight feet) in the laboratory and the wind probably aids in their dispersion (Lewis, 1959). The wheat thrips will sometimes bite man (Borror and DeLong, 1964).

The genus Frankliniella Karny contains several common and important species. F. occidentalis is the very abundant but harmless western flower thrips, F. fusca is a pest on seedling cotton and F. insularis is the vector of spotted wilt disease in tomatoes. In the West Indies, however, F. parvula, the cacao flower thrips is important in the pollination of the cacao crop (Billes, 1941). The biology of this genus is of the typical kind for Terebrantia with oviposition in tender parts of leaves. The flower thrips will also oviposit in fruit and flower parts (Bryan and Smith, 1956). Experiments by Davidson and Bald (1930) and by Bryan and Smith (1956) showed that temperature markedly affects the rate of development of all stages and the time of development varies inversely with the temperature. All four species pupate in the ground, in cracks or under debris. Except for F. insularis they have very short life cycles and, at warm temperatures, complete a

generation in about two weeks (Eddy and Livingston, 1931) (Bryan and Smith, 1956). F. insularis requires over twice as long (36 to 39 days) to complete its life cycle (Davidson and Bald, 1930). This species is also peculiar in that both winged and wingless forms of both sexes occur (Eddy, 1931). The adult females overwinter at the base of the host plants and in the spring produce male progeny, and mate with these to produce the succeeding generation (Eddy and Livingstone, 1931). In spring reproduction is very rapid. Bailey (1933b) noted that by late spring in California almost every flower head contains several adults and larvae.

The pear thrips Taeniothrips inconsequens (Uzel) is a European species introduced into the United States on fruit trees. Williams (1916) indicated that T. inconsequens (Uzel), and T. pyri Daniel were synonymous and, although no taxonomic clarification could be found, in view of early publication dates and identical life histories it seems likely that Euthrips pyri Daniel is also the same species. The life history of the whole group will be described under the common name pear thrips.

The life history of the pear thrips is quite unique in that about ten months of the year is spent hibernating underground (Williams, 1916). The adults begin to emerge from the ground through cracks or softened soil in February and continue through March. They may be present by the millions in a pear or cherry orchard when the young buds begin to open and their feeding destroys the buds. If the food supply is depleted they all migrate to a new orchard (Moulton, 1909a). Oviposition begins as soon as fruit and leaf stems and young fruit begin to develop and the eggs are placed just under the epidermis of these structures.

Hatching occurs in four to eight days and the larvae begin to feed on the leaves and fruit (Foster and Jones, 1911). The larvae grow very rapidly and by the time they are full grown in two to three weeks, they are larger than the adults. They then drop from the tree, enter the soil, and form cells, within which they remain without food until fall (Moulton, 1909a). Moulton (1907) found that the larvae still retained green undigested chlorophyll in their bodies in late August. Pupation occurs within the cell in autumn and the adults are fully mature by December to February, but remain in the soil until the trees are budding. Only one generation per year is completed and reproduction is strictly parthenogenic (Moulton, 1907).

One of the best known and most widely distributed of the predaceous thrips is the black hunter Leptothrips mali (Fitch). The adults of both sexes hibernate from October to March, under loose bark or cracks or old spider webs or the fruit trees. They become active again by the end of March, but larvae do not appear before the last of April. A second generation of larvae occurs in late June and early July and a small third generation in August. The eggs are known to be deposited singly on the lower leaf surface, but the length of incubation has not been determined because of the difficulty of rearing this restless species in the laboratory. The larval stage lasts about 12 to 15 days after which they seek out a protected place on the host or in ground debris to hibernate. The prepupal and the two pupal stages last six to ten days. The reproductive capacity is very low. In rearing experiments done by Bailey (1940a) mated females never produced more than one larvae. The black hunter preys on the eggs of scale insects, the peach twig borer, the adults and larvae of other thrips, mites, and red spider eggs. The

feeding is done by piercing and sucking as in phytophagous, and they can live a few days on plant juices if other food is unavailable (Bailey, 1940a). Reproduction in Leptothrips mali is bisexual, but in a closely related genus, Haplothrips subtilissimus, reproduction is strictly parthenogenic with no males known (Putman, 1942).

Another predaceous species, Scolothrips sexmaculatus (Pergande), is in the suborder Terebrantia. It has three black spots on each front wing and is commonly called the six-spotted thrips (Borror and DeLong, 1964). It is predaceous on the red spider and plant feeding mites. In feeding, this predator holds the spider down with the front legs and rolls it over before inserting the mouthparts. It takes about 15 to 20 minutes to suck the juices from a spider and one half to one minute to consume a spider egg. It rests for long periods between meals, however, and this lack of voraciousness together with the small numbers prevent it from being very beneficial. If the population becomes too dense, they become cannibalistic and weak or injured individuals are also killed. Other species of thrips, however, are not attacked. The females only lay four or five eggs which are inserted into tender plant tissue and hatch in six to ten days. The two larval instars last five to fourteen days and the pupal stages about six days. The larvae feed along with the adults, but the pupae are quiescent under dense spider webs on the underside of leaves. Bailey (1939b) suspects that the adults overwinter but has not been able to discover any overwintering forms. Reproduction is bisexual (Bailey, 1939b).

The banded winged thrips of the genus Aeolothrips Haliday are also predaceous members of the Terebrantia. They prey upon other thrips, particularly the western flower thrips and pea thrips. The larvae of

this genus are very active and are voracious hunters. The most outstanding characteristic of this genus is that it forms a cocoon. When the larvae is mature it crawls into the loose soil or debris to pupate. Pupation may be immediate, but in the species which only produce one brood per year the larvae remain quiet until winter before pupating (Bailey, 1951). In this way, Aleothrips resembles the pear thrips Taeniothrips inconsequens, but the pear thrips cell is simply hollowed out of earth, while this group is thought to form its cocoon from a silken thread produced by the Malpighian tubules (Snodgrass, 1935). The thread issues from the anus and is wrapped around the body by twisting the abdomen (Bailey, 1940b).

CHAPTER IV

LABORATORY REARING METHODS

It is necessary to rear thrips in the laboratory for several different types of research. Several generations of known parentage are needed for genetic and taxonomic studies, and it is also necessary to use reared specimens for disease transmission experiments and for determining life histories and habits of a species. Since thrips are difficult to collect in large numbers and are almost impossible to obtain in winter (Munger, 1942), material must be reared for almost all research involving the Thysanoptera.

Because of the small size and secretive habits of thrips, conventional insect rearing methods are not suitable (Bryan and Smith, 1956). Three problems are commonly encountered in rearing thrips; the construction of a good cage, the selection of a suitable host plant or animal, and the development of efficient manipulating techniques.

Cages

A thrips cage must be tight enough to prevent them from escaping or becoming wedged into cracks, yet it must be ventilated to prevent moisture from condensing and drowning them. In addition, it should facilitate the manipulation of the thrips as much as possible (Sakimura, 1961), and should be transparent on one side to allow observation (Munger, 1942). Sakimura (1961) stipulated that no opening larger than .0025 inch should

occur in a good cage. The type of cage most useful in a particular situation depends, of course, upon the purpose of the experiment, the laboratory facilities available, and many other factors, but several types of cages can be suggested.

One of the most simple cages for mass rearing is made of a potted host plant and a lamp globe. The globe is sealed to the flower pot with plasticine, and the small upper end of the globe is covered with silk or some other fine woven material (Davidson and Bald, 1930). Bryan and Smith (1956) made use of lipped vials covered by muslin cloth. The cloth was held in place over the open end of a vial by using a rubber band wrapped tightly around the vial below the lip. Sakimura (1961) used 125 ml. Erlenmeyer flasks layed on the side or lengths of glass tubing with dacron cloth for the ventilated covering. Eddy and Livingstone (1931) were able to confine very young larvae in test tubes plugged with cotton but for other stages, particularly larvae ready to pupate, cotton is not satisfactory. Putman (1942) wrapped the cotton stoppers of rearing vials with gauze. This served very well for caging Haplothrips subtilissimus, but it should be pointed out that this species is much larger and less active than most of the thrips. The cage made from a glass container covered with cloth can be variously modified so long as it is escape-proof, yet air permeable.

Some use has been made of transparent polyethylene bags or plastic sheeting for cages. Plastic sheeting can be rolled into a cylinder of the desired diameter and fastened with acetone. The ends can be covered with cloth or one end can be pressed into the soil around a host plant (Sakimura, 1961). George (1961) sealed an inverted polyethylene bag over a potted host plant and ventilated and inflated the cage with

compressed air. A small puncture near the top of the bag (and presumably the compressed air inlet) was screened with cloth. This cage has the advantage that some manipulation through the bag is possible without breaking the seal. Bailey (1933) developed a very versatile cage for thrips with permeable cellophane envelopes. Envelopes of various sizes could be used to enclose a single leaf, a larger twig, or a branch. The open end of the flexible bag is constricted tightly around the petiole or stem and the basal end can be left on the growing plant or inserted in water. Such permeable cellophane can also be used in lieu of cloth as a covering for other cages (Bailey, 1933a).

Another very simple cage can be made by floating a leaf in a petri dish of water or sucrose solution. A ring of some "sticky" substance is drawn around the edge of the desired feeding or ovipositing area. If this cage is kept in subdued light at a cool temperature, the thrips are less active and fewer become trapped in the sticky ring (Sakimura, 1961).

Several workers have used various modifications of a "sandwich" cage. Munger (1942) developed a complex cage composed of eight layers of wood, cloth, rubber, glass and plaster. A leaf of the host formed the floor of the actual cage cavity and below the leaf was an assembly to cushion the leaf and keep it moist. Two layers of perforated glass, parallel to the leaf blade, and separated with a ring of dental plaster formed the sides of the cage. The hole in the upper piece of glass was covered with fine cloth. The cavity of the cage was 2 1/8 by 3 1/2 by 3/8 inches (Munger, 1942). A modification of this cage used by Bryan and Smith (1956) made use of 1/8 inch thick Lucite rather than glass. One Lucite plate with a 3/4 inch hole in it was placed over the leaf and a

second unperforated Lucite plate was placed over the first to form the roof of the cavity. Sakimura (1961) described a sandwich cage made of a piece of felt with a 3/8 inch hole cut out and a piece of 15 mil plastic sheeting on each side. The layers of a sandwich cage must be held together with equal pressure on all sides so that no cracks occur between the layers.

Special problems arise in rearing thrips for virus transmission studies. Thrips must be allowed to feed on a limited area of a growing plant and the plant must not be damaged by the cage. Storey (1928) developed such a rearing method in his work with a leafhopper vector of maize streak disease. Davidson and Bald (1930) adapted this technique for use with Frankliniella insularis in transmissions of spotted wilt disease in tomatoes. A spring clip on a wire stake supported the glass rearing tube in a convenient position over a tomato plant. One end of the tube was held flush against a leaf which was pressed up gently from beneath by a cork stopper on a spring. The other end of the tube was plugged with cottonwool. Using this method all stages of thrips could be exposed to a very limited area of a diseased or healthy, growing plant.

Hosts

The selection of a suitable host plant or animal depends upon the species, but the natural host is not always the best for use in laboratory rearing (Sakimura, 1961). If a plant has crevices or overlapping leaves, the thrips are difficult to observe or retrieve. Flowers are not suitable, but flower-feeding species can be reared on fruit or folliage such as bean pods or cabbage midribs (Sakimura, 1961). The

host must be acceptable for food, must be tender enough for oviposition and must not wilt or spoil before the eggs hatch (Bryan and Smith, 1956) (Munger, 1942). The host plant should also be available throughout the year and should be suited to the type of cage used (Bryan and Smith, 1956). Bryan and Smith (1956) used two different host plants for different stages in the life cycle. Oviposition was on string bean pods and after hatching the larvae were left on this host until the first instar was completed. Then they were transferred to the leaves of wild radish, (Raphanus sativus L.), which would fit into the sandwich cage much better than the bean pods. It is usually necessary to examine the host plants (Bryan and Smith, 1956) or rear them in isolation (Shull, 1914) to avoid introducing into the experiment wild thrips or eggs, that might be on the plants.

Predaceous species have entirely different food requirements. It is usually necessary to feed them live prey or eggs. Putman (1942) reported that Haplothrips subtilissimus was easy to rear. He fed them insect eggs which were introduced into the cage on waxed paper. Bailey (1940a) found Leptothrips mali very difficult to rear. They were restless and continuously tried to escape even though their natural food, mites, was provided in the cage. With predaceous species it is often necessary to increase the humidity if no plant material is in the cage. Putman (1942) did this by storing the ventilated cages in a jar with moistened plaster of paris. In providing food for phytophagous species it is important not to put more plant material in the cage than is needed or the danger of water condensation will be increased. Sakimura (1961) suggested the use of a small piece of blotter paper in the cage and also a fairly constant temperature as aids in preventing condensation.

Sakimura and Carter (1934) used an artificial feeding apparatus by putting a fish skin membrane over a three per cent cane sugar solution. This was successful for all stages except the very young larvae which were unable to pierce the membrane.

Manipulating Techniques

Thrips are difficult to manipulate during rearing experiments because of their small size, fragility, and their tendency to hide in any crack or crevice available. Also the adults of many species are extremely active and can crawl, jump, or fly very rapidly.

It is usually desirable to make initial field collections of the larval stage. Munger (1942) suggested the use of a collecting box with a screen at the top and a removable black plate underneath. Infested plants or twigs are beaten against the screen and the larvae fall to the plate below. Larvae are rather slow moving and can be transferred to a cage by use of a moistened fine-tipped camel's hair brush (Sakimura, 1961). Adults are usually too active to manipulate with a brush. A small aspirator fitting a 15 by 25 millimeter vial can be used to manipulate them. For best results they should be approached suddenly at the head end. The adults are less active if placed in a cool place before transfers are made (Sakimura, 1961). Munger (1942) placed a drop of chloroform on a piece of cotton over the ventilation hole of the cage for about a minute to quiet adults before transferring them to another cage. Numbers of adults can be brushed into a new cage in this way rather than being collected individually. If the brush is dipped in a fine powder the thrips will not adhere to it. Sakimura (1961) suggested the use of a 10 x jeweler's lens attached to the glasses or forehead of the

experimenter for use in manipulating thrips.

Females are usually allowed to feed and oviposit on a portion of plant tissue for about 24 hours. The plant tissue is then removed to a separate vial for hatching. The used leaves may be soaked in distilled water for 24 hours (Eddy and Livingstone, 1931) or wrapped in moist cotton (Eddy and Clarke, 1930) to restore moisture to them. After the minimum incubation period for the species, the plant material is observed under the microscope daily and larvae are transferred with a fine brush to a new vial. Young larvae are very fragile, however, and transferring should not be done unless necessary for the experiment. When the larvae approach maturity they seek a crevice in which to pupate. In a rearing cage they usually select an angle or corner of the glass. Munger (1942) developed a lure to collect all the pupae into one place and facilitate observations. Two cover slips with a fragment of glass between them were glued together so that they formed a slanting crevice between them. The two glasses touched on one side and slanted to 0.4 mm opening at the opposite side. Citrus thrips pupae congregated where the crevice was 0.2 mm high. By placing such a lure on the floor of the cage, almost all pupae can be retrieved. A constant temperature of 87.5°F and a relative humidity of 50 per cent was found optimal for citrus thrips (Munger, 1942). If satisfactory conditions can be maintained, thrips can be reared in the laboratory indefinitely and no loss of vigor occurs (Munger, 1942).

CHAPTER V

CONCLUSIONS

Life histories have been determined for relatively few of the known species of Thysanoptera. The biologies of many species are totally unknown. The groups considered in this study are all similar in some respects, but vary in other characteristics. The piercing, sucking mouthparts and the method of feeding are almost identical for all species. The type of metamorphosis is also fairly constant. Most species feed on various parts of plants, but several species are entirely predaceous on arthropods and arthropod eggs. There are a few thrips that seem to be omnivorous to some degree. Oviposition is different for the two suborders; the Terebrantia insert their eggs into plant tissues while the Tubulifera simply lay the eggs on the leaf surface. The nature of the pupal stage is perhaps the most variable characteristic. Some pupae remain among the feeding adults and larvae while others penetrate the soil. Some species seek out a natural crevice, some hollow out a cell, and others spin a cocoon. Some thrips are active only about one month each year, others can reproduce and remain active throughout the year in warm climates. It is probable that as more species are studied and as better rearing techniques are developed, the phylogeny of the group will be clearer.

Due to the method of feeding of phytophagous thrips, any species is a potential vector of plant viruses. Therefore, pure research on

any species might be of indirect economic value.

Relatively little work has been done on developing techniques for rearing thrips in the laboratory. Several basic cages and manipulating techniques have been developed, and these can be modified to suit a particular experiment and laboratory situation. Practice and a thorough knowledge of the life history and exact requirements of a species is necessary for successful rearing of thrips in the laboratory.

LITERATURE CITED

Bailey, S. F. 1933a. The biology of the bean thrips. Hilgardia 7:467-522.

_____. 1933b. A contribution to the knowledge of the western flower thrips, Frankliniella californica (Moulton). Jour. Econ. Ent. 26:836-840.

_____. 1935. Thrips as vectors of plant disease. Jour. Econ. Ent. 28:856-863.

_____. 1939a. The mullein thrips. Pan-Pac. Ent. 15:111-116.

_____. 1939b. The six-spotted thrips, Scolothrips sexmasculatus. Perg. Jour. Econ. Ent. 32:43-46.

_____. 1940a. The black hunter, Leptothrips mali. (Fitch) Jour. Econ. Ent. 33:539-544.

_____. 1940b. Cocoon-spinning Thysanoptera. Pan-Pac. Ent. 16: 77-79.

_____. 1951. The genus Aeolothrips Haliday in North America. Hilgardia 21:43-80.

Billes, D. J. 1941. Pollination of Theobrona cacao L. in Trinidad, B. W. I. Tropical Agriculture 18:151-156.

Borror, D. J. and D. M. DeLong. 1964. An introduction to the study of insects. Rev. Ed. Holt, Rinehart & Winston, Inc, New York. 819 pp.

Bryan, D. E. and R. F. Smith. 1956. The Frankliniella occidentalis (Pergande) complex in California. Univer. of California Publications in Entomology 10:359-410.

Davidson, J. and J. G. Bald. 1930. Description and bionomics of Frankliniella insularis Franklin. Bull. of Ent. Res. 21:365-385.

Ealand, D. A. 1921. Insect life. A & C Black Ltd., London. 340 pp.

Eddy, C. O. 1930. F. fusca. South Carolina Agric. Exp. Station Report 43:61-62.

Eddy, C. O. and W. H. Clarke, 1930. The onion thrips on seedling cotton with a seasons record of parthenogenic development. Jour. Econ. Ent. 23:704-708.

Eddy, C. O. and E. M. Livingstone. 1931. F. fusca on seedling cotton. South Carolina Agric. Exp. Station Bull. 271:1-23.

Flosom, J. W. 1922. Entomology. P. Blakinton's Son & Co., Philadelphia. 502 pp.

Foster, S. W. and P. R. Jones. 1911. How to control the pear thrips. U.S.D.A. Bureau of Ent. Circular No. 131. 24 pp.

George, J. A. 1961. A pneumatic laboratory cage for Thysanoptera. Canadian Entomologist 93:564-565.

Hinds, W. E. 1902. Contribution to a monograph of the insects of the order Thysanoptera inhabiting North America. Proceedings of the U.S. National Museum 26:79-242.

Howard, L. O. 1907. The insect book. Doubleday, Page & Company, Garden City, New York. 429 pp.

Imms, A. D. 1934. A general textbook of entomology. Methuen & Co. Ltd., London. 727 pp.

Lewis, T. 1959. The annual cycle of Limothrips cerealium Haliday Thysanoptera and its distribution in a wheat field. Entomologia Experimentalis et Applicata 2:187-203.

Moulton, D. 1907. The pear thrips. U.S.D.A. Bureau of Entom. Bull. No. 68, Part I. 16pp.

_____. 1909. The pear thrips and its control. U.S.D.A. Bureau of Entom. Bull. No. 80, Part IV., pp. 51-66.

Munger, F. 1942. A method of rearing citrus thrips in the laboratory. Jour. Econ. Ent. 35:373-375.

Post, R. L. and W. J. Colberg. 1958. Barley thrips in North Dakota. North Dakota Agricultural College Extension Service Circular A-292. 6 pp.

Post, R. L. and G. Olson. 1960. Barley thrips. North Dakota Seed Journal.

Putman, W. L. 1942. Notes on the predaceous thrips Haplothrips subtilissimus Hal. and Aeolothrips melaleucus Hal. Canadian Entomologist 74:37-43.

Russell, H. M. 1909. The greenhouse thrips. Bureau of Ent. Bull. No. 64. Part IV, pp. 43-60.

_____. 1912a. The greenhouse thrips. U.S.D.A. Bureau of Ent. Circular No. 151. 9 pp.

_____. 1912b. The bean thrips. U.S.D.A. Bureau of Ent. Bull. No. 118. 45 pp.

_____. 1912c. The red-banded thrips. U.S.D.A. Bureau of Ent. Bull. No. 99, Part II. 29 pp.

Sakimura, K. 1961. Techniques for handling thrips in transmission experiments with the tomato spotted wilt virus. Plant Disease Reporter 45:766-770.

Sakimura, K. and C. Carter. 1934. The artificial feeding of Thysanoptera. Annals of the Ent. Soc. of Amer. 27:341-342.

Sharga, U. S. 1933. Biology and Life history of Limothrips cerealium Haliday. An applied biol. 20:308-326.

Shull, A. F. 1914. Parthenogenesis in Anthothrips verbasci. Sixteenth Annual Report of Michigan Academy of Science. pp. 46-48.

_____. 1917. Sex determination in Anthothrips verbasci. Genetics 2:480-488.

Snodgrass, R. E. 1935. Principles of insect morphology. McGraw-Hill, Inc., New York. 667 pp.

Storey, H. H. 1928. Transmission studies of maize streak disease. Annals of Applied Biology. 15:1-25.

Wigglesworth, V. B. 1964. The life of insects. World Pub. Co., Cleveland, Ohio. 360 pp.

Williams, C. B. 1916. Notes on British Thysanoptera. Entomologist. 49:275-284.

_____. 1918. Notes on some Trinidad thrips of economic importance. Plant Diseases and Pests. 17:143-146.

VITA

Sharon Clairene Young

Candidate for the Degree of

Master of Science

Report: LIFE HISTORIES AND REARING TECHNIQUES OF REPRESENTATIVE SPECIES OF THE ORDER THYSANOPTERA

Major Field: Natural Science

Biographical:

Personal Data: Born in Elk City, Oklahoma, August 3, 1942, the daughter of Clair E. and Eva Mae Young.

Education: Attended grade school and junior high school at Crawford and Berlin, Oklahoma; graduated from Cyril High School, Cyril, Oklahoma in 1960; attended Southwestern State College, Weatherford, Oklahoma, in the summer of 1960; received the Bachelor of Science Degree with a major in Biology from Bethany Nazarene College in May, 1964; completed the requirements for the Master of Science degree in August, 1965.