AN INVESTIGATION INTO THE RELATIONSHIP BETWEEN WESTERN FLOWER THRIPS DAMAGE AND ORCHARD FLOOR MANAGEMENT IN BRITISH COLUMBIA APPLE ORCHARDS

by

Tamila L. Hubscher

B.Sc., Simon Fraser University, 1983

PROFESSIONAL PAPER SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF PEST MANAGEMENT
in the Department
of
Biological Sciences

SIMON FRASER UNIVERSITY

December 1988

APPROVAL

Name:	Tamila Louise Hubscher
Degree:	Master of Pest Management

Title of Professional Paper:

AN INVESTIGATION INTO THE RELATIONSHIP BETWEEN WESTERN FLOWER THRIPS DAMAGE AND ORCHARD FLOOR MANAGEMENT IN BRITISH COLUMBIA APPLE ORCHARDS

Examining Committee:

Chairman: Dr. M. Winston, Professor

Dr. J.E. Rahe, Professor, Senior Supervisor

Dr. J.H. Borden, Professor

Dr. N. Angerilli, Eastern Indonesia University Development Project (EIUDP), S.F.U.

Dr. D. Gillespie, Agassiz Research Station, Agriculture Canada, Agassiz, B.C., Public Examiner

Date Approved 22 December 1988

Title of Thesis/Project/Extended Essay

An Investigation Into The Relationship Between Western Flower Thrips Damage And Orchard Floor Management In British Columbia Apple Orchards

Author:

(signature)

Tamila Louise Hubscher

(name)

December 28, 1988

(date)

ABSTRACT

The western flower thrips *Frankliniella occidentalis* is a general flower feeder with a wide host range that includes apples and dandelions. Flowers provide the thrips with food, a protective habitat and oviposition sites. The western flower thrips has the potential to cause three types of damage to its hosts: damage to the fruit, reduced photosynthetic capacity due to feeding on the leaves and transmission of plant pathogens. Oviposition by thrips into apple fruits can cause the fruit to abort or to develop an irregular shaped blemish called a pansy spot, caused by a physiological reaction of the fruit. Apples with large or numerous pansy spots are downgraded which results in a direct financial loss to the orchardist. The current recommended control for western flower thrips is to apply an insecticide spray at petal-fall. Since adult thrips enter the apple blossoms at the pink stage of development and migrate to new hosts as soon as the flowers start to wither, this petal-fall spray is often too late to control the thrips. The application of insecticides during the bloom period is not recommended because of the risk of honey bee poisoning. The majority of orchardists mow the orchard ground cover just prior to bloom to eliminate dandelion blossoms. The dandelions are thought to compete with apple blossoms for honey bee pollination. It is possible, however, that mowing forces the thrips from dandelions to apple blossoms in greater numbers or sooner than would otherwise be the case.

Mowing did not increase the numbers of thrips caught in the flower clusters, on sticky traps or increase the damage in the mowed plot compared to the control plot. When there was a significant difference between the number of thrips caught per trap per day between the upper and lower sticky traps, the upper traps always caught significantly more thrips than the lower traps. There were no positional effects caused by the location of the trap trees on the number of thrips caught in the sticky traps. The majority of the pansy spots observed were small.

ACKNOWLEDGEMENTS

I would like to thank my senior supervisor, Dr. James Rahe, for his advice and guidance. I would also like to thank my supervisory committee, Dr. John Borden and Dr. Nello Angerilli, for their helpful comments and suggestions. I will always be in debt to Mr. W. Ritchie, Mr. M. Herz and Mr. B. Harker for allowing me to conduct my research in their orchards. I would also like to thank Dr. J. Procter, Mr. J. Parsons, Mr. T. Swales, Mr. D. Sharp, and Mr. J. Price for their advice in selecting field sites. Ms. H. Sampson supplied me with all the weather records for Cawston, B.C.. I would also like to thank Mr. D. Bergvinson for reviewing all the chemical names listed in this paper. Finally, I would like to thank Ms. G. Anderson and Ms. K. Tricker for assisting me in the set up of my plots and for supplying advice and moral support.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Objectives

The objectives of this paper are two-fold: to review the literature on the western flower thrips and to investigate the impact of dandelion management by mowing on the level of thrips damage in British Columbian apple orchards.

Introduction

Apples are the third largest agricultural cash crop in British Columbia (Lee 1986). The main source of competition is from Washington state where six times the amount of apples grown in British Columbia are produced (Lee 1986). Washington state not only competes through the volume of apples grown, but also produces an earlier, more cosmetically homogenous crop than British Columbia's. British Columbia can remain competitive in the apple industry only if it produces apples of a higher quality, or different varieties than the United States. Consumers equate colour and size with good taste and quality (Walsh 1976); therefore British Columbia must produce the ideal apple - moderate sized, and approaching 100% in bright red colouration. To produce this product, orchardists must control the causal agents of cosmetic damage on their fruit. Cosmetic damage is damage which affects the appearance of the fruit but not its quality. One type of cosmetic blemish is the pansy spot which is associated with thrips oviposition sites (Bailey 1933). In the 1930's, consumers began to demand apples of a higher quality and therefore more emphasis was placed on controlling thrips (Bailey 1938).

The western flower thrips causes "silver-spotting" or pansy spots, poor set and malformed or stunted fruits (Bailey 1933). Pansy spots do not reduce the quality of the fruit in anything except appearance. In British Columbia, McIntosh, Golden Delicious, Northern Spy, Spartan (Madsen and Jack 1966) and Newtown are susceptible varieties (Anonymous 1987). Rome, Jonathan, Gravenstein and Red Delicious are reported to be susceptible in California, where the causal agent is *Thrips madroni* (Swift and Madsen 1956). Nonsusceptible varieties are able to 'overcome' the oviposition damage leaving only a scar that can easily be mistaken for a lenticel (Swift and Madsen 1956).

Oviposition in the young, newly pollinated apples destroys plant cells which are not regenerated, resulting in the typical pansy spot blemish. Numerous ovipositions into the stamen and style can cause these tissues to wither and prevent pollination (Boyce 1955; Sharma and Bhalla 1963). Unfertilized flowers and severely damaged fruits are dropped at the calyx stage. Damaged fruits may also be aborted at the 'June-drop' stage of apple development. Boivin and Stewart (1982) observed that a large proportion of insect punctured apples were aborted by the tree. Although the immature stages of the thrips do feed in the tree, there is no evidence that they damage the fruit (Madsen and Jack 1966). Thick pubescence on the young fruits may protect them from the nymphal thrips.

The incidence of thrips damage is often sporadic (Haley 1976; Madsen and Jack 1966). The current methods of predicting when thrips populations will peak in orchards are unreliable and research has often been undertaken in years of low thrips population levels. Therefore the data collected has often been ambiguous (H.F. Madsen[1], personal communication). This fact is evident in the literature, where reported thrips damage ranges from neglible, 0.8% (Madsen *et al* 1975), 1% at harvest (Madsen and Carty 1977), to fairly severe, 13% at petal fall (Swift and Madsen 1956) and 25% at harvest (Newcomer 1921).

---

[1] Formerly with Agriculture Canada Summerland Research Station, Summerland, B.C., deceased August 1987.

Newcomer (1921) reported pansy spot damage caused by thrips on apples but did not identify the species.

Interviews with fieldmen and extension personnel have indicated that thrips are generally a minor pest in the Okanagan Valley, and are slightly more severe in the Similkameen Valley (T. Swales[2], J. Procter[3], D. Sharp[4], J. Price[5], J. Parsons[6], personal communications). In a survey by Haley (1976), 16% of growers questioned said that they considered thrips a major pest. Seventeen percent of the same growers stated that codling moth, *Laspeyresia pomonella* (L.), was a major pest and 22% reported no serious problems. Codling moth is the key orchard pest in British Columbia. The high level of concern about thrips was due to the difficulty in controlling them (S. Haley[7], personal communication) and not due to high levels of thrips in previous years (Madsen *et al* 1975).

Biology of *Frankliniella occidentalis*

Description of F. occidentalis

Frankliniella (=Euthrips) occidentalis (= california = canadensis = claripennis = dahliae = gossypiana = helianthi = moultoni = obscura = trehernei = venusta) (Pergande) (Thysanoptera : Thripidae) was described by Pergande (1895). The orginal specimens were collected from apricot, orange, potatoes, and "different kinds of weeds". The description of *F. occidentalis* is as follows : size ranging from 0.9 mm to 1.88 mm in length; eyes are black and hairy;

---

[2] Okanagan-Similkameen Growers Fruit Union, Osoyoos, B.C.

[3] B.C. Ministry of Agriculture and Fisheries, Penticton, B.C.

[4] Vernon Fruit Union, Winfield, B.C.

[5] B.C. Ministry of Agriculture and Fisheries, Vernon, B.C.

[6] B.C. Ministry of Agriculture and Fisheries, Oliver, B.C.

[7] University of Oregon, Department of Biology, Eugene Oregon

ocelli are reddish; the head is twice as long as broad; the eyes occupy 2/3 or more of the sides of the head; the antennae have 8 segments (segments 7 and 8 are the smallest; they form the 'stylus'; segments 3 and 6 are the longest and not equal in length to each other); the pedicel is not thickened distally; the wings are fringed and have two veins running longitudinally; the anteromarginal and anteroangular setae on the pronotum are similar in length; and the posterior marginal comb on the abdominal tergite VIII is complete (Pergande 1895; Bailey 1938; Allen and Broadbent 1986). Bryan and Smith (1956) showed that *F. occidentalis* has several colour morphs within the population, ranging from pale to dark. Pergande (1895) only described the pale colour morph. Bryan and Smith also recorded body lengths for females to be 1.27 mm to 1.88 mm, slightly longer than those recorded by Pergande. They synonomized several species (*F. californica, F. canadensis, F. claripensis, F. dahliae, F. gossypiana, F. helianthi, F. moultoni, F. obscura, F. trehernei, F. venusta*) with *F. occidentalis.*

Distribution

The western flower thrips until recently was thought to occur from British Columbia to Mexico (Bryan and Smith 1956). Its spread across the continent has occurred fairly rapidly. In 1983 it was recorded in Georgia (Beshear 1983), but in Canada no further east then Alberta (Steiner and Elliott 1983). By 1987, *F. occidentalis* was well established in Ontario and Nova Scotian greenhouses and had been collected on field crops in Ontario as well as in Quebec (Broadbent *et al* 1987). *F. occidentalis* has also been collected from the Canary Islands, Columbia, Costa Rica, Denmark, France, Hawaii, Japan, Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland and West Germany (Bartlett 1988). The western flower thrips probably attained its world wide distribution as a result of the movement of plant material.

Thrips have been recorded as high as 3,300 m in the air (Glick 1939). The distribution of thrips within the first 9.14 m of air above the soil surface was found to be homogenous (Johnson 1969).

Life- History

The western flower thrips overwinters as a sexually mature female in the soil, in curled leaves, under bark, and in evergreen plants (Bailey 1938). The adults emerge in the spring and fly upward, where they are caught by air currents (Lewis 1970). The thrips locate a host plant, and begin to feed and oviposit. The eggs are inserted into the plant tissue at right angles to the surface, and begin to hatch in approximately four days at 26.5° C. (Bryan and Smith 1956). The nymphs feed on plant tissues. At 26.7° C. the first moult occurs in 1 to 2 days. The second stadium lasts approximately three days. The thrips then drops either to the ground or to a protected crevice of the plant (Bailey 1938; Broadbent 1986) moults into a quiescent, psuedopupal stage that lasts 4 to 5 days during the summer (Bailey 1938), and then pupates in a loosely constructed cell, in soil near the host plant, or in crevices on the host plant (Bailey 1938). The adult emerges from the soil and moves to the host plant. The exoskeleton hardens and gains its full colour in approximately 48 hours.

There is an unsubstantiated suggestion in the literature that female *Thrips imaginis* locate males using a male produced pheromone (Kirk 1984b). In the Thripidae the female may or may not mate prior to oviposition. Parthenogenic reproduction, which produces only male offspring in thrips, is determined by the environment, the season, the geographical region and the availability of males (Bryan and Smith 1956; Morison 1957). In a general discussion on thrips mating behaviour Morison (1957) reported that if the conditions are conducive to sexual reproduction, the female and male will mate without a period of courtship and males are polygamous.

Female western flower thrips can live up to 40 days under laboratory conditions (Bryan and Smith 1956), and 21 days in field cages (Bailey 1938). Males are shorter lived then females (Bailey 1933).

Oviposition occurs within 72 hours of adult eclosion (Bryan and Smith 1956). Bryan and Smith (1956) report egg production of 0.66 to 1.63 eggs per day per female at 26.6° C. If the female lives a maximum of 40 days, she will thus produce 26 to 65 eggs in her lifetime. Bailey (1938) reports a maximum egg production of 20 eggs per female, close to the low end of Bryan and Smith's calculated fecundity. Both of these figures agree with those for other Thripidae species (Lewis 1973).

Host Searching and Selection

Thrips are poor fliers and have no control over their flight in wind speeds in excess of 3.2 kph (Taylor 1962). The average flight speed of a thrips is 0.8 to 1.1 kph (Lewis 1959). In most cases, the thrips are blown into all types of objects in the path of the wind. If the thrips impacts with a host plant, it usually remains, if not it may take off immediately or sometime later. In periods of calm, thrips may cue in on host plants using the senses of sight and smell (Lewis 1965).

F. occidentalis is a general flower feeder, found on at least 139 species of plants (45 families and 23 orders) (Bryan and Smith 1956, Appendix A) Adult flower thrips usually remain in a flower until it withers or otherwise becomes unsuitable (Bailey 1938). The flowers provide a source of pollen for sexual maturation and growth of *Frankliniella intonsa* (Kirk 1985a). Trichilo and Leigh (1988) observed that *F. occidentalis* did not require pollen to for normal sexual maturation and adequate fecundity in order to sustain population growth. Although a higher fecundity was realized with pollen or mite eggs (*Tetranychus urticae* Koch) included in the diet of the thrips. The flower also provides shelter; flowers that are simple, ('open') and offer poor shelter harbour fewer thrips than more intricate flowers

(Bryan and Smith 1956). Finally, the female thrips oviposit on all parts of the leaves, flowers and stem of the flower cluster. Eggs are inserted into the parenchyma cells at right angles to the surface (Bryan and Smith 1956).

Several authors have researched chemical attractants for thrips. Penman *et al* (1982), found that ethyl nicotinate was more attractive to *Thrips obscuratus* than ripe peaches or apricots. *F. tritici* was found to be attracted to the following compounds, (listed in order of attractiveness): cinnamylaldehyde, salicylaldehyde, anisaldehyde, benzyl alcohol, cinnamylalcohol, benzaldehyde, nitrobenzaldehyde (ortho), nitrobenzoic acid (meta) and oil of almonds (true) (Morgan and Crumb 1928). It appears that these chemicals were tested because the majority of them are aromatics and therefore have very distinctive odours. Other authors have noted that anisaldehyde increased thrips catches for several species of flower dwelling thrips {*Thrips major, Thrips flavus, T. pillichi* and *Frankliniella intonsa* (Kirk 1985b)}, while benzaldehyde, salicylaldehyde, and cinnamylaldehyde (Howlett 1914) attracted unindentified flower thrips.

White without ultraviolet reflectance is reportedly the most attractive colour to *F. occidentalis*, followed by yellow and blue (Lewis 1959; Moffitt 1964; Kirk 1984a), but violet coloured traps may be even more attractive (R.S. Vernon[8], personal communication). Since apple blossoms are mainly white, they are very attractive to the western flower thrips. Although white traps are attractive, thrips are poor fliers and are so often blown by the wind, that sticky traps often sample the density of thrips in the air stream and not the population density of thrips in the desired area (Taylor 1962; Lewis 1973). It is recommended that an anemometer be used in conjunction with sticky traps, so that the number of thrips per volume of air passing the trap can be calculated (Taylor 1962). There are no references to the effective distance of sticky traps, in fact, there is only one reference to the reaction of thrips to objects distant to them. In studies of host preference, thrips (*Thrips fuscupennis, T. tabaci, T. major, T. imaginis, Aeolothrips intermedius, Ceratothrips*

---

[8] Agriculture Canada, Vancouver Research Station, Vancouver, B.C.

ericae, Haplothrips leucantheini, and Kakothrips pisivorus) enclosed in a gelatin capsule with pollen, could not detect pollen at a distance of more than 1 mm from them (Kirk 1984c). This observation does not indicate that thrips are only able to see objects which are closer then 1 mm from them, but that they were only able to detect the pollen within that distance under those experimental conditions. However they probably locate the pollen by smell and not sight.

Kirk (1985b) observed that when anisaldehyde was added to white (without uv) traps, catches of *T. major, T. flavus, T. intonsa and T. pillichi* were increased by 3.3 to 8.3 times. The combination of traps plus anisaldehyde and/or cinnamaldehyde for the capture of thrips was patented by Uchida in 1973.

Kirk (1985a) observed that *Haplothrips tardus* recognize their host plant by its pollen. Host plants with their pollen removed were not recognized, but the term 'recognize' was not defined. Western flower thrips feed in cucumber blossoms which do not produce pollen (D.R. Gillespie[9], personal communication), so therefore host 'recognition' is more complex than Kirk reported. When the host becomes unsuitable, either through lack of pollen, withering of the bloom or a disturbance, the thrips leave the host and begin to search for a new host.

Thrips flight is favored by temperature in the range of 19-21°C. (Lewis 1964), lack of strong wind, high light intensity, low relative humidity, host plant unsuitability and the correct stage of sexual development (Morison 1957). Most of the thrips caught during migratory flights were immature females (Lewis 1965).

---

[9] Agriculture Canada Research Station, Agassiz, B.C.

CHAPTER II

DAMAGE

Thrips Damage in Apple Orchards

Large numbers of western flower thrips can cause economic loss to orchardists in three ways: 1) pansy spots on fruit which result in direct cullage, 2) feeding damage which reduces the photosynthetic area, which in turn reduces the carbohydrate fixation and the vigour of the plant, and 3) disease transmission.

The pansy spot blemish is a physiological reaction to the presence of a thrips egg in the tissue of a young fruit (Newcomer 1921). They can range in size from a small dark circle marking the puncture spot (Newcomer 1921; Venables 1925) to several centimeters in diameter. According to Madsen and Procter (1982), a fruit with a pansy spot greater than 2.2 cm in diameter is downgraded, which results in a direct economic loss to the orchardist. I have observed that the actual tolerance level for pansy spots in the packinghouses can be much lower. The tolerance level for pansy spot is much higher than for some other types of cosmetic damage, however in the case of mirid damage, blemishes greater than 2 mm in diameter cause the fruit to be downgraded (Prokopy and Hubbell 1981). Increased demand for cosmetically perfect fruit by consumers can cause apples with even small pansy spots to be downgraded.

Adults and nymphs also cause damage as a result of feeding on host plants. Thrips have highly modified assymetrical mouth parts that allow the thrips to puncture the epidermis of the plant and then suck out the contents of the ruptured cells (Borden 1915). Feeding injury may also produce pansy spots, but they are not as well defined as those resulting from oviposition (Madsen and Jack 1966). Large numbers of thrips feeding on flowers and young fruits can cause the fruit to drop, the flowers to be aborted, and the fruit to be malformed (Borden 1915; Venables 1925; Boyce 1955; Pradesh 1963; Sharma and Bhalla 1963). Madsen and Jack (1966) found no evidence to suggest that blossom drop had occurred due to thrips damage on apples. My own experience supports this observation. Orchardists require only 3 to 5% of the total blossoms of an average bloom to develop into harvested fruit, so a large amount of blooms can be aborted before there is an economic loss (Prokopy and Hubbell 1981).

Western flower thrips can transmit viral, bacterial and fungal diseases to their host plants (Bailey 1935). Tomato spotted wilt virus (TSWV), with a host range including tomato, potato, lettuce, tobacco, gladiolus, onion, chilli and pineapple is vectored by the western flower thrips (Lewis 1973). Venables (1925) noted that tomatoes also develop pansy spots. A typical pansy spot type blemish was observed by Allen and Broadbent (1986) on tomato. However, the blemish was attributed to TSWV. Boivin and Stewart (1982) observed that most *Campylomma verbasci* (Meyer) damage is the result of mechanical damage and not a reaction to a toxin. Therefore, it is possible that the black spot damage is due to the mechanical damage are caused by thrips oviposition, and that the pansy spots caused by TSWV or a similar virus. The western flower thrips has been shown to vector fire blight, *Erwinia amylovora* (Venables 1925). Bailey (1935) reported that fungal spores were found on the surfaces of the bodies of thrips and therefore they can function as vectors of fungal diseases.

In British Columbia apple orchards, the greatest thrips damage is caused by oviposition into young developing fruits by the females. The incidence of thrips damage in orchards is unpredictable and sporadic (Madsen and Jack 1966). In some years the damaged fruits have composed 25% of the crop (Venables 1925). Athough the economic injury level can vary in different areas and years, the standard for economic injury level is 5% of the crop (Free 1970; McGregor 1976; Morse and Brawner, 1986). Currently, it is recommended that a petal-fall spray of diazinon[10] be applied in orchards that have a history of thrips damage

---

[10] For information on chemicals listed, see appendix B

(Anonymous 1987). Although this is the recommended control method for thrips, the spray is applied too late to prevent pansy spots in some years. Thrips enter the blossoms as soon as they open, so the ideal time to control thrips is during the bloom period. Spraying insecticides during bloom is not recommended, however, because of toxicity to both domestic and wild pollinators (Anonymous 1987). If orchardists must apply an insecticide during the blossom period, than it must be applied in such a manner as to reduce the risk of bee poisoning. However there are several ways to apply an insecticide during the bloom period so as to reduce the risk of bee poisoning: 1) remove all the hives from the orchard prior to spraying and return them when the risk period is over, 2) close the bee hives during the risk period, and 3) spray the insecticide at night when the bees are no longer foraging (the insecticide must have a fairly short residual period). The decision to return the bee colonies to the orchard following an insecticidal treatment must be determined by the orchardist based upon the degree of risk acceptable and the level of pollination necessary for a successful crop.

Recently, a computer simulation model (REDAPOL) has been developed which considers the level of pollination, the risk level of thrips damage, weather and site specific orchard data, and from this information a recommendation is given about a management program for thrips (DeGrandi-Hoffman *et al* 1988). The model has only been tested in small experimental plots throughout the United States, and requires testing in large commerical orchards before it can be put into widespread use by commerical growers. If this model does prove to have widespread applicability, it could be easily incorporated into an integrated pest management program for apple orchards, to reduce the risk involved in timing of an insecticidal spray for thrips.

CHAPTER III

CONTROL

Biological Control

Many natural enemies of thrips occur (Table 1). Most attempts at using biological control agents to control thrips have occurred on greenhouse crops. A few biological control agents have been documented in field crop situations.

Predators

Froggatt (1931) recorded a species of ant, *Iridomyrmex rufoniger*, preying on the plague thrips in Australia. There is no mention of the efficacy of this predator or under what conditions it became a factor in controlling the thrips populations. More recently, *Iridomyrmex* sp. was reported to control thrips in laboratory experiments (Kirk 1984b). The potential of *Iridomyrmex* as a biological control agent has not been investigated under field conditions. Most species of ants are general predators. If *Iridomyrmex* utilizes a wider host range in the field than in the laboratory, its effectiveness as a biological control agent would be reduced. Another ant, *Plagiolepis* sp., has been reported to prey on thrips (Lewis 1973), but there is no further information available on its potential as a biological control agent.

Anthocorids have been mentioned in reducing thrips populations in apple orchards (Kumar and Anathakrishnan, 1984), but fluctuations in environmental conditions reduce their effiency. An Anthocorid, *Montandoniola morguesi*, was successfully used to control Cuban laurel thrips, *Gynaikothrips ficorum*, on banyan trees (*Fiscus* sp.) in Hawaii (Lewis 1973). This predator was able to respond to increases in thrips populations within two weeks of outbreaks. However, the climate of the Okanagan Valley is very much drier and colder than that of Hawaii. *Orius tristicolor* (Anthocoridae) has been recorded to prey on thrips in the

Table 1. Predators, parasites and pathogens of thrips, geogragphic location and reference.

Predators	**Location**	**Reference**
Iridomyrmex rufoniger	Australia	Froggatt 1931
Iridomyrmex sp.	Australia	Kirk 1984b
Plagiolepis sp.		Lewis 1973
Montandoniola moreguesi	Hawaii	Lewis 1973
Orius tristicolor	Canada	Lewis 1973
Campylomma verbasci	Canada	Thistlewood 1986
Chrysopid (larvae)		Lewis 1973
Neuroptera		Lewis 1973
Aeolothrips fasciatus	U.S.A./Canada	Childs 1927
Haplothrips niger	Canada	Madsen and Jack 1966
Leptothrips mali	U.S.A./Canada	Bailey 1940; Madsen and Jack 1966
Heliothrips haemorrhoidalis	U.S.A.	McMurtry 1961
Typhlodromus sp.	U.S.A.	MacGill 1939
Euseiulus hibisci	U.S.A.	Tanigoshi *et al* 1985
Amblyseius cucumeris	Holland	Ramakers and VanLieberg 1982
Amblyseius mckenzieii	Holland	Ramakers and VanLieberg 1982
Coleoptera (Coccinellids)		Lewis 1973
Spiders		Lewis 1973
Reptiles		Lewis 1973
Amphibians		Lewis 1973
Mammals		Lewis 1973
Parasites		
Thripoctenus americensis	Canada	Thompson 1950
T. russeli	U.S.A.	Muesbeck *et al* 1951
T. brui	Japan/U.S.A.	Sakimura 1937
Megaphragma mymaripenne	U.S.A.	McMurtry 1961
Xysma ceanothae		Krombein 1958
Trichogrammatidae		Lewis 1973
Mymaridae		Lewis 1973
Chalcidiodae	U.S.A	Wilson and Cooley 1972
Howardula aptini	England	Sharga 1932
Pathogens		
Entomophthora sp.	U.S.A.	Carl 1975
E. parvispora	U.S.A./Europe	MacLeod *et al* 1976
E. thripidum	Holland	Samson *et al* 1979
Verticullum lecanii		Hall 1981; Binns *et al* 1982
Beauveria bassiana		Lewis 1973

Okanagan Valley (Lewis 1973), but predator population levels are too low to alter thrips population levels significantly during bloom. *Campylomma verbasci* (Miridae) present in the orchards during bloom have been recorded to prey on mites and other small insects (Thistlewood 1986). Unfortunately, *C. verbasci* also feeds on the small apples and causes a cosmetic injury to the fruit which is often confused with thrips damage. It is unadvisable to enhance *Campylomma* populations to control thrips, due to their potential to cause more damage than the thrips. Several authors report that *C. verbasci* does not cause damage on the McIntosh variety of apple (Prokopy and Hubbell 1981; Thistlewood 1986). If a grower had an isolated block of McIntosh apples, then using *C. verbasci* as a biological control agent might be an option, as long as the mirids could not migrate to a susceptible block of apples.

Chrysopid larvae are also reported to prey on thrips, but no attempts have been made to use them as biological control agents (Lewis 1973).

Three species of predatory thrips, *Leptothrips niger*, *Haplothrips mali* and *Aeolothrips fasciatus*, are present in orchards, but are not present in significantly large numbers at the time when flower thrips cause damage (Childs 1927; Madsen and Jack, 1966). The predatory thrips *Leptothrips mali* controlled *F. moultoni* in laboratory experiments, but in orchards they prey on mites and aphids as well as thrips, which reduces their efficiency as biological control agents (Bailey 1940). A predatory thrips, *Franklinothrips vespiformis* (Crawford) preys on greenhouse thrips, (*Heliothrips haemorrhoidalis*) in California avocado groves. This predator consumed a large number of prey, but not enough to control a heavy population (McMurtry 1961). As *F. vespiformis* is not an effective control agent for pest thrips in its native habitat, it is unlikely that it would be a successful biological control agent for thrips in the Okanagan.

Other predators of thrips include several species of beetles, lacewings (Bailey 1938) spiders, mammals, reptiles, amphibians and birds (Lewis 1973), but they have little impact upon the size of the population.

A mite, *Typhlodromus* sp., preys on *T. tabaci* in greenhouses (MacGill 1939), consuming 5 to 6 thrips in a day. *Euseiulus (=Amblyseius) hibisci* has been able to regulate populations of *Scirtothrips citri* at near-zero levels throughout the critical injury period (April and May) in lemon and orange orchards (Tanigoshi *et. al.* 1985). Another predatory mite, *Amblyseius cucumeris* Oudemans has been field tested in the Okanagan valley to control *Frankliniella occidentalis* with inconclusive results (N. Angerilli[11], personal communication). *A. cucumeris* in combination with *A. mckenzieii* have been successfully used to control *Thrips tabaci* in greenhouses (Ramakers and VanLieberg 1982) Recently *A. cucumeris* has been investigated for its commerical viability in British Columbia cucumber and green pepper greenhouses; it shows great potential for future use (Gillespie 1988). In most instances, biological control is preferred over chemical control in greenhouses because it does not upset existing biological control programs for whiteflies and mites.

Parasites

Although thrips are very small, several internal parasites have been recorded. The wasp *Thripoctenus americensis* Girault. (Eulophidae) parasitizes *Frankliniella occidentalis* in Canada (Thompson 1950). No attempts at using it for a biological control agent have been reported. A chalcidoid wasp planidium (=larvae) (not identified to species) was collected from immature *F. occidentalis* in North America (Wilson and Cooley 1972). Up to three planidia were collected from each nymph, with no adverse effect upon the host. *Thripoctenus russelli* is a parasite of *F. tritici* in California (Muesbeck *et al* 1951), but is never numerous enough to control thrips under field conditions (Bailey 1938). A closely related species, *Thripoctenus brui,*

---

[11] Eastern Indonesia University Development Project, Simon Fraser University, Burnaby, B.C.

was found to not only parasitize *Thrips tabaci*, but also *Frankliniella formosae* (Sakimura 1937). *Megaphragma mymaripenne* Timberlake, parasitizes the eggs of the greenhouse thrips, *Heliothrips haemorrhoidalis* (McMurtry 1961), and is considered to be the most important natural enemy of this thrips. Some avocado groves have reported up to 75% parasitism of thrips eggs by this wasp. A solitary wasp, *Xysma ceanothae* (Viereck), was observed to prey on an unidentified species of thrips (possibly Thripinae) (Krombein 1958). Wasps in the families Trichogrammatidae and Mymaridae have been recorded as egg parasites of thrips (Lewis 1973), but there is no record of these wasps being able to regulate thrips populations. In general, many species of wasps have been reported to parasitize thrips, but very little is known of their impact on host populations.

Nematodes in the family Allantonematidae parasitize thrips in temperate regions of the world (Lewis 1973). One Allantonematid, *Howardula (=Anguillulina) aptini* (Sharga), was first recorded to attack *Aptinothrips rufus* in England (Sharga 1932). Infestations as high as 78% have been observed (Lysaght 1937). The nematode does not alter the appearance of the thrips in any way, but causes degeneration of the ovaries and reproductive failure (Lysaght 1937). The peak production of eggs for *H. aptini* is during April and May (Lysaght 1937), which make it a suitable biological control agent for early thrips infestation. *H. aptini* have been collected in *F. vaccinii* and *Taeniothrips vaccinophilus* Hood, in New Brunswick (Nickle and Wood 1964), and from *F. occidentalis* in Texas (Wilson and Cooley 1972). One female thrips was found to be carrying 44 nematodes.

Pathogens

The environmental conditions in greenhouses (high humidity and constant temperatures) have led several researchers to investigate the use of fungi to control thrips. Most of the research has been done on *Entomophthora* species. Carl (1975) investigated an unidentified *Entomophthora* sp. that is specific to the Thripidae. The diseased nymphs change colour from yellow to black, which facilitates monitoring the usually rapid spread of the disease. Although this fungus shows potential to control thrips in greenhouses, it is not suitable for field situations. In the field natural epizootics only occur late in the season with the onset of nightly dews, and fructification of the fungus is arrested at temperatures below 13° C.. Even if the grower applied fungal spores in the spring, the low nightly temperature would prevent the spread of the disease. Another promising biological control agent which attacks *Thrips* spp. is *E. parvispora.* This fungus causes moribund insects to move to the upper leaves of the plant, which increases the efficiency of spore dispersal. Like other *Entomophthora* sp., it requires a relative humidity of 70% or greater to sporulate (MacLeod Tyrell and Carl 1976). *E. thripidum* also causes parasitized thrips to move to the tops of plants (Samson Ramakers and Oswald 1979). Researchers noted that they did not observe a resting spore stage of *E. thripidium* and it was very short lived at room temperature, which would preclude its commerical utility until these problems can be overcome. It was also observed that dissemination of the disease via contact of healthy and diseased thrips was inconsistent, which would decrease the biological control potential of this agent.

Hall (1981) suggested that *Verticillim lecanii* might be a potential biocontrol agent in greenhouses. This fungus has a wide host range (scales, aphids, Coleoptera, Collembola, Diptera, Hymenoptera, mites, rusts, powdery mildews, and contact lenses)(Hall 1981). In greenhouses it can cause 100% mortality of aphids and scales with no adverse effects on *Phytoseiulus persimilus, Tetranychus urticae, Encarsia formosa* or warmblooded animals. There is no mention in the literature of *V. lecanii* affecting thrips but due to its broad host range, I suggest that it should be investigated as to its efficacy in controlling greenhouse thrips. Since sporulation requires temperatures above 11.5° C and high humidities, it would appear to have limited potential in field situations (Hall 1981).

Lewis (1973) mentions that deep ploughing of cereal stubble can lead to mortality of thrips due to *Beauveria bassiana* in the soil. Mortality may also be due to the inability of the emerging thrips to reach the soil surface.

Bacillus thuringiensis var. thuringiensis (*Bt*) was shown to have no effect on *F. occidentalis* in field experiments (Shorey and Hall 1963). It is thought that the method of feeding of thrips (rooting and sucking) results in insufficient ingestion of *Bt*, and therefore *Bt* is a poor control agent (D.R. Gillespie[12], personal communication).

Biorational Chemicals

Grout and Morse (1986) observed that avermectin B had an insecticidal effect on *Scirothrips citri*. In field tests, Morse and Brawner (1986) observed a fair efficacy of avermectin. Of several insect growth regulators (IGRs) tested in the field UC84572 and cyromazine were the most effective (Grout and Morse 1986). The IGRs increased first instar mortality, and nymphs did not develop past the prepupal stage. There were no lethal effects on the adults, but a reduced number of progeny was observed. Although the idea of using IGRs to control thrips in apple orchards is very appealling, it is not very practicable. The stage of *F. occidentalis* which causes most of the damage is the overwintering female, and IGRs have no affect on the adults. Treating the immature thrips in the fall is not feasible because of the migratory nature of the thrips.

In conclusion, many biocontrol agents show great potential for controlling thrips in greenhouses, but limited potential for controlling thrips in field crops, such as apples. The most promising are predatory mites in field crops and IGRs for greenhouse crops.

---

[12] Agriculture Canada Research Station, Agassiz, B.C.

Chemical Control

Almost every class of insecticide known to man has been tested to control thrips. In a summary of chemical control programs against thrips, Bailey (1938) (Appendix B) listed the following materials: sulfur washes, sulfur dusts, tobacco decoctions, kerosene soap, nicotine sulfate, pyrethrum, flurosilicates, rotenone-containing mixtures and arsenicals. These compounds produced inferior results due to poor timing of sprays or poor penetration. Newcomer (1921) recommended that a spray of miscible or distillate oil and nicotine sulphate be applied at pink (a stage of apple flower development) to control thrips. In the 1940's, control programs for thrips shifted to the chlorinated hydrocarbons, mainly BHC, DDT, aldrin, dieldrin and toxaphene (Lewis 1973). DDT was first tested in British Columbia in 1943 (Morgan and Madsen 1976). These insecticides were applied as sprays, dusts and drenches depending upon the crop and the lifestage that was to be controlled. Although they at first provided adequate control for thrips, by the mid 1950's several species of thrips developed resistance. Botanicals (derris, pyrethrum and nicotine) were tested but never replaced the chlorinated hydrocarbons.

Organophosphates (OP), such as parathion, carbophenothion, methyl carbophenothion, methyl demeton, ethion, malathion, dicrotophos and carbaryl showed systemic action and therefore were very effective at controlling thrips in inaccessible parts of the plant. Parathion was the most effective. Lynch, Garner and Morgan (1984) observed that systemics did not control flower thrips on peanuts and that 70% of the total economic loss was due to the cost of insecticide.

One OP, dicrotophos, was reported to prevent immigrating coffee thrips from reproducing, but not from causing some feeding damage. Resistance to OP's was encountered in the late 1970's.

Since the development of resistance to OPs, researchers have investigated other groups of chemicals. In cotton, TEMIK® 15G (aldicarb) and Counter® 15G gave good control of *F. tritici* and *F. fusca* (Hopkins and Moore 1982). TEMIK® would be unsuitable for use on apples, because it has a high mammalian toxicity. It may only be used in British Columbia by registered pesticide applicators for use on selected greenhouse and field crops (Miller and Craig 1980). Laster *et al* (1984) found that the combination of monosodium methanearsonate (MSMA) amd dinoseb, or dinoseb alone, reduced the number of thrips, but not to a level at which they could be considered controlled. *F. vaccinii* was successfully controlled on blueberries using a dust of ethion or carbophenothion with no more bee toxicity than dieldrin. Although ethion is very toxic to mammals, it has a low level of toxicity to *Apis millifera* (Anonymous 1981a). Ethion is currently recommended for control of the apple rust mite, European red mite and rosy apple aphid. Ethion should be applied at night, when the pollinators are no longer foraging (Anonymous 1987), and can therefore be integrated into current orchard practices.

Synthetic pyrethroids have proven to be effective. Fenvalerate provided better control than permethrin (Chalfant and Young 1984) of *Frankliniella* spp. on peanuts. Chalfant and Young (1984) also found that carbaryl and acephate when applied by chemigation resulted in 88% and 75-82% reductions, respectively, in thrips. Verma (1979) tested several chemicals (fenitrothrin, monocrotophos, fenthion, Bidrin® and phosalone) on thrips on apple trees. They all provided significant control of thrips. Verma did not mention the effect these insecticides had on pollinating insects. Dimethoate reduced grape thrips on Okanagan Riesling and Verdelet varieties of grapes by nearly 100% (F.L. Banham[13], 1987 unpublished data). In California, citrus thrips have already developed resistance to dimethoate, so it may have short term use in apple orchards (Anonymous 1981b).

---

[13] Agriculture Canada, Summerland Research Station, Summerland, B.C.

Currently, research into the control of thrips in greenhouses has combined several techniques. Thripstik®, a 50/50 mixture of polybutene and deltamethrin (mixed in water), applied to the container bags of greenhouse cucumber plants provided control of *F. occidentalis* for ten weeks (Pickford 1984). Unfortunately, this treatment is too expensive and inconvenient for use in apple orchards.

It appears that thrips are able to develop resistance to insecticides in relatively short periods of time. This is due to their being faculative asexuals (all offspring of resistant mothers are resistant) and to having short generation times and numerous generations per year. Since the use of chemical insecticides to control thrips is limited due to bee toxicity, poor penetration, resistance and lack of registered materials, other control alternatives must be used.

Cultural Control

Cultural control techniques *i.e.* manipulation of the environment to control a pest, have been used successfully to control many species of thrips. The majority of cultural control techniques for thrips have been applied against species which are less migratory than the western flower thrips and generally are leaf feeding.

It was observed that irrigation could decrease the number of thrips in several crops (Mumford and Hey 1930; Bullock 1963). Correct irrigation decreases the amount of stress on crop plants and therefore increases their resistance to attack by leaf feeding thrips. It was also observed that flooding fields prior to planting decreased the number of emerging overwintering thrips. Increased soil moisture can also increase the incidence of fungal diseases attacking the pupae. Flooding of apple orchards is not advisable as apples cannot tolerate excess soil moisture for long periods of time and thrips can reinvade the orchard as a result of migration from untreated areas.

Deep ploughing can also increase the mortality of soil dwelling thrips. In order to be effective, the soil must be ploughed to a depth of 25 cm, so that adults cannot reach the surface (Kurdjumov 1913; Kolobova 1926; Bailey 1938; Grivanov 1939; Lyubenov 1961). Burning crop debris can also destroy thrips remaining on the crop after harvest. Neither of these techniques are applicable to apple orchards.

Crop rotation has proven successful in controlling insects of annual crops, but unfortunately apples are perennials. Vertinghoff-Riesch (1958) was able to reduce damage on larch caused by leaf feeding thrips species by planting larch in mixed age blocks interspersed in blocks of hardwood trees. The idea is to 'hide' the larch in a mixed stand so the thrips cannot orientate to the host tree. Once again it is impractical to plant apples in this arrangement. Also the western flower thrips has a large host range and can disperse over long distances to find suitable hosts. Barrier crops have also proven effective (Sakimura cited by Lewis 1973); they act in much the same way as in the larch experiment. Barrier crops are either more attractive to the pest or they prevent the pest from finding the crop.

Aluminium foil mulches around the base of rose plants were used successfully to prevent thrips infestations (Ota and Smith 1968). It is thought that the aluminium foil prevents the thrips from orienting to the plant. Ota and Smith (1968) observed that the aluminium foil mulch only repelled thrips within 60 cm of the mulch. It would be impractical on a crop such as apples, where the first branches are often higher than 60 cm from the ground. This method works well on a small scale, but it is much too labour intensive on a large scale. It may also affect the orientation of honey bees and other pollinators of the apples blossoms.

Finally, the control of weeds or alternative host plants can reduce a pest population within a crop. Most orchards do contain cover crops of a mixture of grasses, perennials and blooming annuals. These cover crops modify the orchard's environment and supply suitable habitats for predators and pests. An orchardist can modify the composition of the vegetation in his orchard, but he has no control over the surrounding land. In the case of the western flower thrips, the ideal situation would be to destroy all the thrips in their overwintering habitat before the orchards become attractive, but unfortunately this cannot be done. Orchards in British Columbia are often surrounded by vast areas of uncultivated rangeland, which are simply too expansive to manage for the control of the western flower thrips.

Cultural control tactics are often desirable because they cost little for the farmer to implement. In the case of the western flower thrips in apple orchards only weed management appears to have potential, and that is limited to the orchard and its surrounding margins.

CHAPTER IV

ORCHARD FLOOR COVER, POLLINATORS AND THRIPS

The majority of British Columbia apple orchardists maintain a cover crop in their orchards. Cover crops affect the orchard environment by altering moisture, nutrient availability and physical properties of the soil, and the prevalence of weeds, plant pathogens and insect pests (Altieri and Schmidt 1986). Some authors contend that cover crops compete with the crop for valuable nutrients and water (Stott 1976; Atkinson and White 1981; Skroch and Shribbs 1986) other authors believe that cover crops contribute more than they subtract from the crop (Edwards and Lofty 1978; Atkinson and Herbert 1979; Altieri 1981; Eastop 1981). Hogue (1986) contended that all orchard floor management systems have advantages and disadvantages and that the orchardist must decide which method to utilize based upon the requirements of his orchard.

Orchard cover crops are usually composed of Kentucky Blue Grass (*Poa pratensis*), quack grass (*Agropyron repens*), orchard grass (*Dactylis glomerata*), dandelions (*Taraxacum officinale*), white clover (*Trifoluim repens*) and various other annual and perennial plants (E. Hogue[14], personal communication). In apple orchards, dandelions are a host plant of the western flower thrips.

Apple trees are insect pollinated (Free 1964) and orchardists often rent hives of honey bees (*Apis mellifera*) to pollinate their orchards. Kremer (1950) states that although orchardists often assume that dandelions compete with the apple blooms for honey bees, they present their pollen at different times of the day, and close at temperatures above 21.3° C.. Since dandelions, once closed, will not reopen that day, Kremer assumes that the bees will switch to the apple flower. Since only five percent of all apple flowers must set to produce an average crop {136,000 flowers per hectare (Free 1970), McGregor 1976}, Kremer concluded

---

[14] Agriculture Canada, Summerland Research Station, Summerland, B.C.

that there was enough time in a day remaining after the dandelions close for the bees to pollinate the apples sufficiently. Free (1968; 1970) believed that Kremer underestimated the role that dandelions play in orchard pollination dynamics. He observed that most bees foraging on dandelions were only collecting nectar, but dandelion pollen was still the number one pollen collected, even though there were fewer dandelion flowers per row than apple flowers. Free (1970) also noted that foraging bees do not switch over to a new type of flower once the old one is unavailable for that day. Based upon these observations, Free (1970) suggested that orchardists should take steps to reduce the competition between dandelions and apples. Methods of reducing competition are mowing, the use of selective herbicides, moving the bee hives into the orchards after the dandelions have closed for the day (Free 1970), increasing the number of hives per hectare (DeGrandi-Hoffman *et al* 1987) and using honeybee alarm pheromones (isopentyl acetate or 2-heptanone) on the floor of the orchard to prevent bees from foraging in the cover crop (Free *et al* 1985). Other authors support Free and suggest that early blooming spring plants should be controlled to reduce competition for bees (Killian and Meyer 1984; Norris 1986).

Orchardists who follow the recommendations of the British Columbia Ministry of Agriculture and Fisheries (Anonymous 1987) mow their orchards just prior to bloom. Since the western flower thrips may be established in the flowering plants of the cover crop (mainly the dandelions), mowing may disturb the thrips and cause a forced migration. The apple trees are the nearest, most abundant potential host for these thrips, so it is likely that the majority of the migrating thrips will settle in the apple trees. The following research was conducted to observe the effect of mowing orchard floor cover crops on populations of thrips in apple blooms and caught on sticky traps, and on level of thrips damage in apple fruits at 'June-drop' and at harvest.

CHAPTER V

METHODS

Materials and Methods

Several growers in the Cawston area (Similkameen Valley, B.C.), received a questionaire which determined their acreage, varieties grown, key insect pests, practice of mowing, hiring of bees, and their willingness to participate in my research (Appendix C). Three orchards, designated R, H, and Ha, selected for field trials had various factors in common: 1) they were operated by experienced orchardists, 2) each contained large blocks of Spartan, McIntosh and Red Delicious varieties, 3) each was bordered on at least one side by uncultivated land (a source of overwintering thrips), 4) the growers contracted the use of bee colonies for the bloom period, 5) they were pruned and trained using the central leader method and 6) all were approximately 20 years old.

Two 50 m by 50 m plots were established in each orchard. Each plot was surrounded by a buffer of at least two rows of trees. Orchardists were asked to mow one of the plots (their choice) near the beginning of bloom. These plots, subsequently designated treatment plots, were mowed on 4 May in orchard R, and on 5 May in orchard Ha. By mistake both plots were mowed in orchard H, this occurring on 30 April.

Experimental plots in orchard R consisted of the variety Spartan on semi-standard rootstock, planted 6 m by 6 m. The rows ran diagonally to the plot boundaries and alternate trees in each row were designated for blossom sampling. In total, 16 trees in each plot were selected. Experimental plots in orchards H and Ha consisted of the varieties Spartan and McIntosh, respectively. Trees in both orchards were growing on semi-dwarfing rootstocks and were spaced approximately 3.5 m within rows and 6 m between rows. Fifteen trees in each plot of orchard H and Ha were randomly designated for blossom sampling.

Flower clusters were collected from designated trees in the various orchards initially on 16-18 April, and subsequently at regular intervals until the calyx stage was reached (11 May). For each cluster the stage of the king bloom (the first flower to open in the cluster), the number of flowers per cluster, and the number of thrips (adults and larvae) were recorded. A single blossom cluster was selected from each quadrant in the lower portion of each tree at each sampling time. Each blossom cluster was placed in a plastic bag and stored at 4°C. Blossom clusters were processed within 7 to 10 days of collection. Thrips were removed from blossoms using methodology adapted from the procedure described by Taylor and Smith (1955). Two drops of Micro® soap were added to 250 ml of water in a 570 ml Mason jar. The soapy water was poured into the sample bag, and swirled around for a few seconds. The blooms were pulled open to allow complete penetration of the detergent solution during agitation. The water and flower cluster were then poured into the Mason jar. The lid was tightened and the jar was agitated for 30 seconds. The water mixture was poured through a tea seive (81 mesh squares per cm^2) and the flower cluster washed with water to remove clinging thrips. The jar was rinsed with a stream of water from a squeeze bottle. The thrips passed through the mesh into a second Mason jar. The thrips usually remained just below the soap bubble layer and were easily seen. They were then transferred with a pipet to a separate dish for examination under a dissecting microscope. All thrips were preserved in 70% ethanol for subsequent examination and confirmation of species indentification.

Dandelion flowers were sampled from below each quadrant of each sample tree on the same dates that blossom clusters were sampled. A dandelion flower was sampled at a random number (from 1 to 10) in feet away from the base of the tree in each quadrant. If a dandelion flower was not available within the quadrant of the sample tree, a sample was not taken. The dandelion flowers were placed in individual marked plastic bags and stored at 4° C. for up to 10 days until they could be processed. The dandelion flowers were processed using the same technique as for the apple blossom clusters.

Sticky traps were also used to monitor thrips populations. Each trap consisted of a sheet of white cardpaper (44 by 16 cm) laminated on one side with plastic (Domar ® Inc.). The paper was rolled to form a cylinder and fastened to a cedar pole (3.6 m x 5 cm x 10 cm) with two staples, and the plastic side of the white card was coated with Tanglefoot®. The pole was tied to the trunk of a tree (trap tree). Each plot had 4 trap trees and thus 8 sticky traps, 4 above the canopy (3.6 m high) and 4 at mid-canopy (1.8 m high). The trap trees were approximately 10 m from a corner of the plot. The traps were changed at approximately 1 week intervals. The traps were checked for thrips in the laboratory with a hand lens (16x), and thrips adhering to the traps were removed and placed on cards until they could be examined under a microscope. The number of each species of thrips on each trap was recorded.

A new shipment of paper received on 7 June, 1985, was not exactly the same colour as the paper used previously. of trap paper. A paired comparison test was conducted from 17 June to 23 June in orchard H to determine if there was a difference in 'attractiveness' between the two papers. The two types of trap papers were located in the upper position, a cross beam was fastened to the post, and two bars to which the paper was attached were suspended from each end of the crossbeam. The bars were on average 31 cm apart.

At June-drop (the major period of fruit abortion), aborted fruits were collected from beneath the sample trees. One apple from each quadrant of the sample trees was also sampled at this time. All fruits were examined in the lab for the presence of oviposition scars, mechanical damage and other insect damage which might indicate why they were aborted. When there was no physical evidence as to the cause of fruit abortion (the majority of cases), the cause was assumed to be hormonal.

Prior to harvest, all fruits on the sample trees were visually inspected for thrips damage (31 August to 22 September). The number of pansy spots per apple, the size of the spots, and the number of non-affected apples were recorded. For 144 apples, the length and the width of each spot was recorded, which allowed estimation of the size distribution of spots. This technique for determining pansy spot size was selected because it was easy to perform without damaging the fruit; other techniques for estimating size of the spot either required that the fruit be picked or damaged. All apples, following this initial sample, had their spots categorized as small (≤0.5 cm wide), medium (≥0.5 cm to 1.0 cm wide) or large (≥1.0 cm or larger wide). The apples were observed close enough to harvest to ensure that real economic damage was evaluated.

CHAPTER VI

RESULTS

Blossom Samples

In orchard R, a significantly higher number (t test, p=0.027) (Zar 1974) of thrips was recovered in blossoms from mowed than from unmowed plots when these were sampled four days after mowing (Figure 1). Differences of a much smaller magnitude in the numbers of thrips from the two mowed plots in orchard H were observed (Figure 2). There was a substantial increase in the numbers of thrips in blossoms following mowing in orchard H. The data do not permit me to conclude whether these differences are caused by mowing or by other factors. In orchard Ha only 11 thrips were recovered from a total of 480 blossoms sampled from 18 April to 11 May. In all orchards there was a substantial increase in the number of thrips in blossoms after these had opened (Figure 3). There were no significant differences among the numbers of thrips caught in each quadrant of trees when the combined data from all orchards were analyzed (Kruskal-Wallis test, p=0.3146 df=3)(Figure 4). One orchard (orchard Ha) did show a difference (Kruskal-Wallis, p=0.0356 df=3, N=11), but this may have been due to the small number of thrips caught in that orchard. The south side of the tree is generally warmer because it receives more radiant energy from the sun, but this does not appear to effect the numbers of thrips caught in each quadrant.

The numbers of thrips were pooled according to stage of king bloom blossom development (Chapman and Catlin 1976) and transformed (SQRT, x+.5), then compared using analysis of variance (ANOVA). The Student-Newman-Keul's test at p=0.05 (SNK) was used for comparison of means. Significantly more thrips were collected from clusters with open blossoms than in other stages (Figure 3). There was no significant difference in the numbers of thrips caught in the sampled clusters during silver tip, tight cluster, pink and balloon

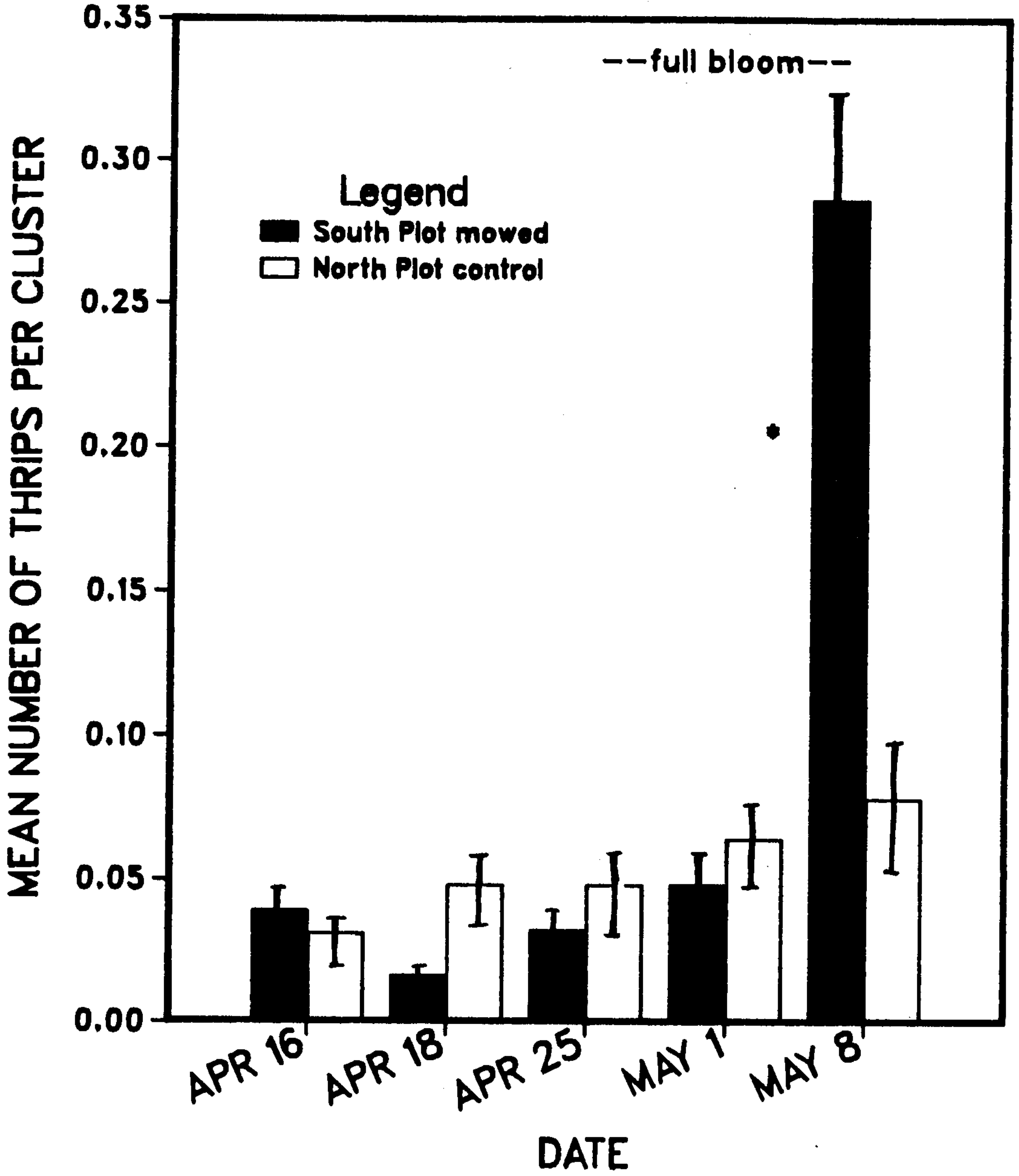

Figure 1. Thrips per flower cluster at various times during the bloom period in orchard R. Asterisk indicates time of mowing.

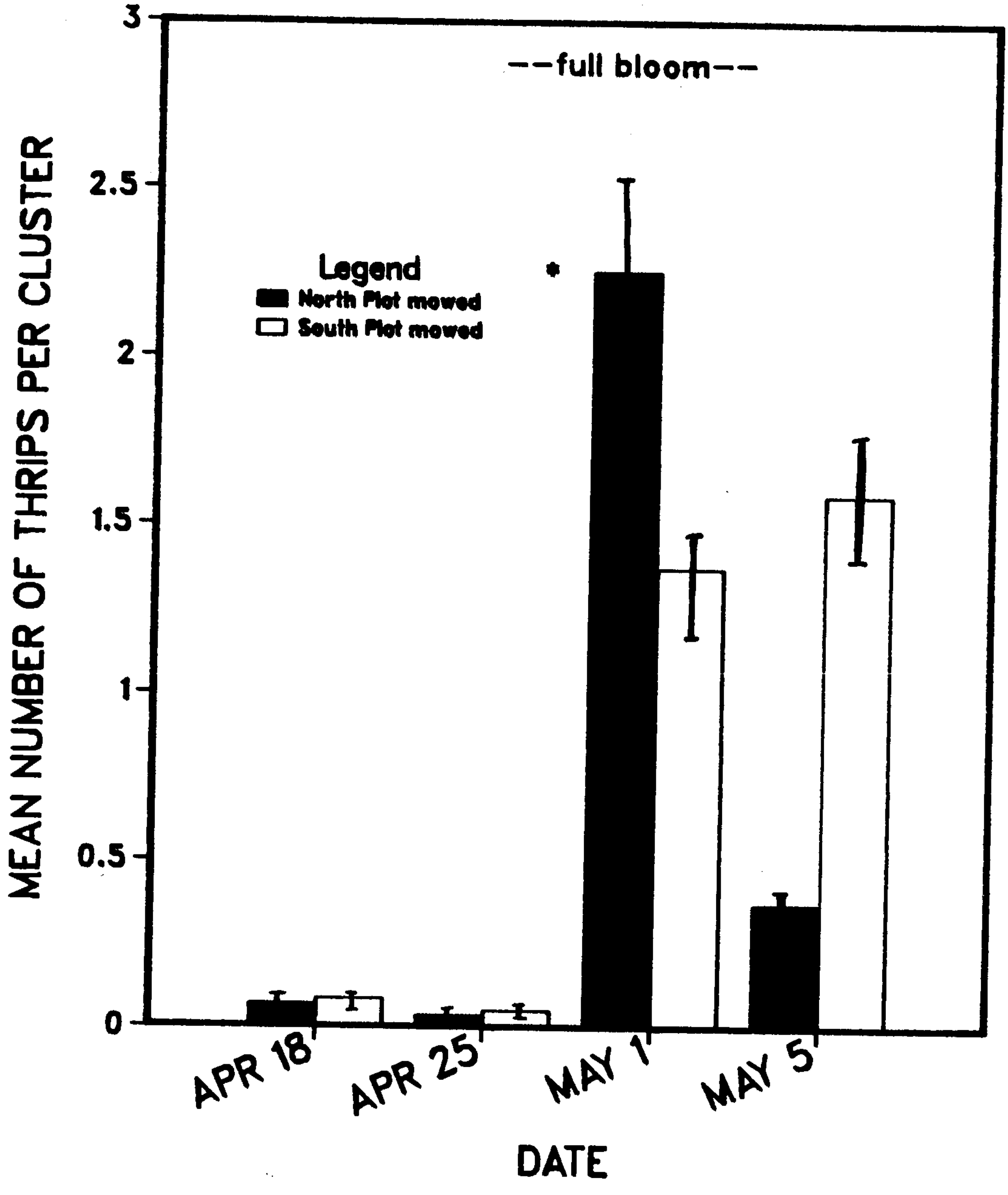

Figure 2. Thrips per flower clusters at various times during the bloom period in orchard H. Asterisk indicates time of mowing.

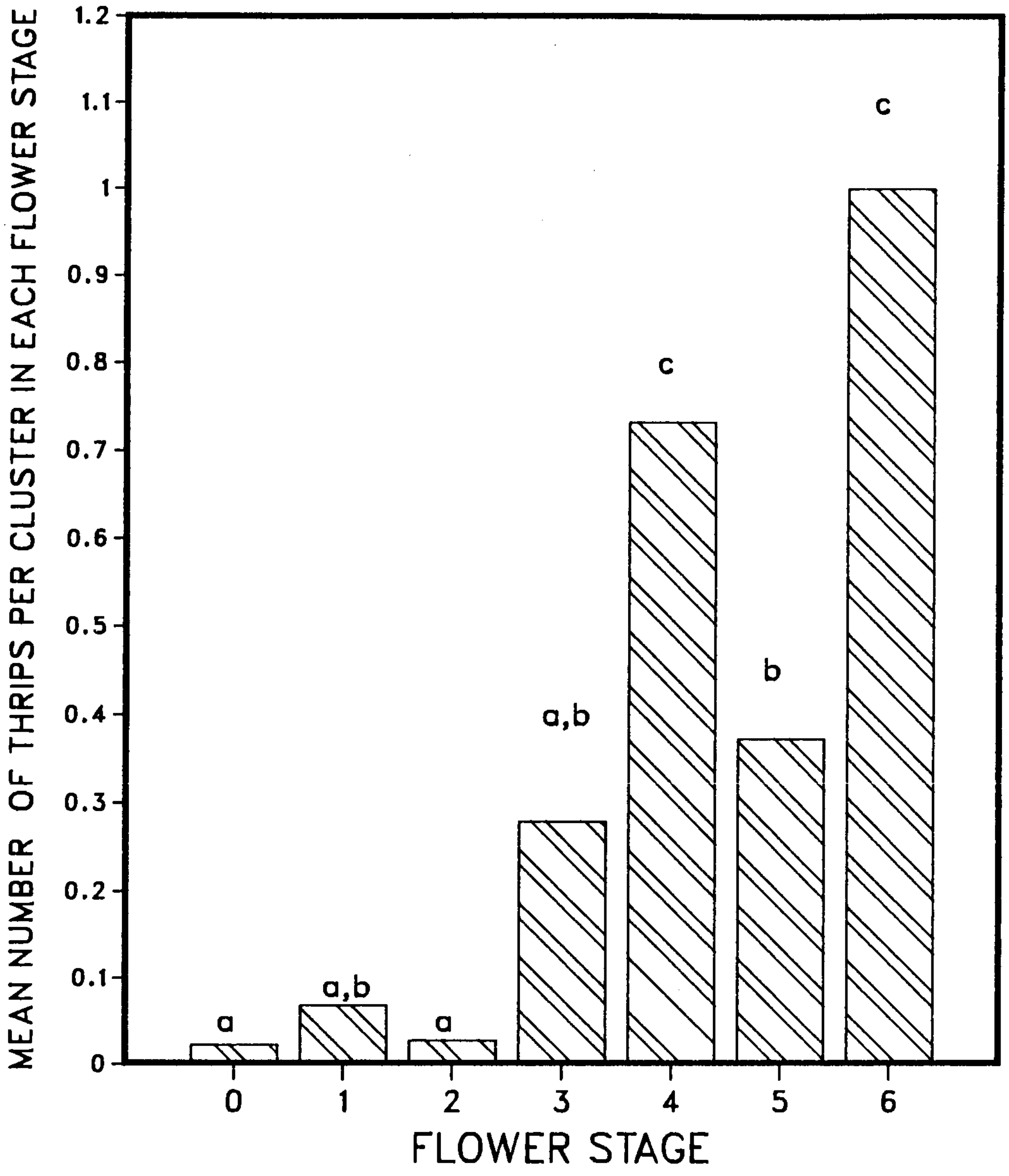

Figure 3. Mean number of thrips per blossom cluster in each stage of apple flower development (all orchards combined). Flower stage: 0=silver tip, 1=tight cluster, 2=pink, 3=balloon, 4=open, 5=full, 6=calyx. Bars labelled with the same letter do not differ significantly, SNK test, p=0.05.

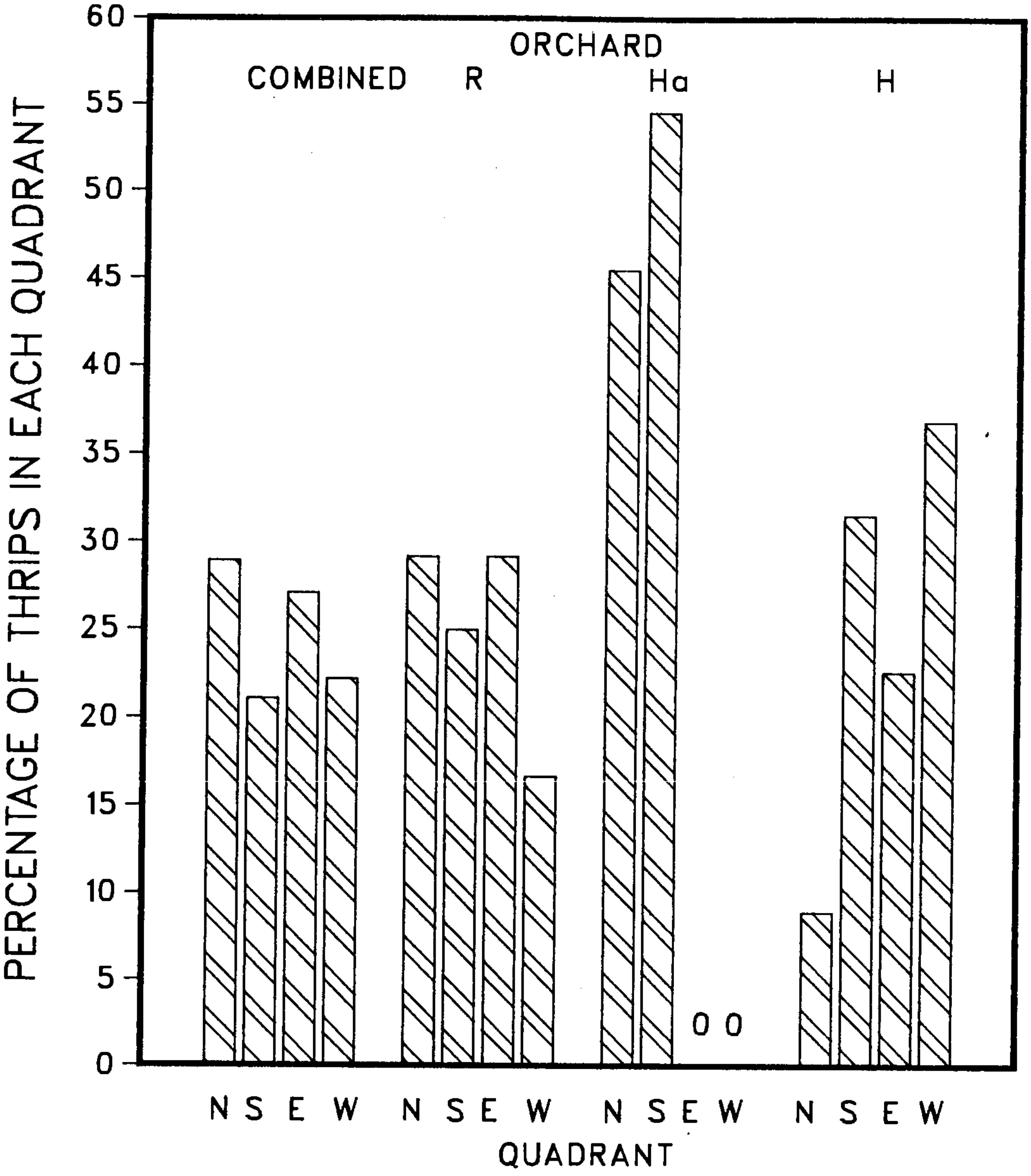

Figure 4. Percentage of thrips collected from blossom clusters from each quadrant of sampled apple trees in orchards R (n= 48), Ha (n= 11) and H (n= 387), (n=total number of thrips in each orchard).

stages of development. All three orchards were significantly different from each other in numbers of thrips collected in the blossom clusters (ANOVA, F=20.68). The 'open' stage of blossom development harboured relatively high numbers of thrips. When the thrips catches for all three orchards for the 'open' stage were analyzed, there was no significant difference between the orchards nor their plots (ANOVA F=10.56). The number of thrips collected in cluster stages 'open', 'full' and 'calyx' in each plot was analyzed using a t test. In orchard R there were significantly more thrips collected in the mowed plot, then in the control plot (t=2.13, p=0.34). There were no differences between the plots in orchard H (t=-0.95, p=0.34).

To determine if mowing had an effect on the number of thrips collected in the 'open', 'full' and 'calyx' blossom clusters, the number of thrips collected in the sample prior to mowing and in the sample after mowing were analyzed (t test). In orchard R there were significantly more thrips in the post-treatment sample than in the sample prior to mowing (t=-2.32, p=0.023), but no significant difference in the control plot (t=-0.23, p=0.82). Unfortunately, this analysis could not be conducted on the samples from orchard Ha and orchard H, as there were no blossom clusters present in the 'open', 'full' or 'calyx' stages of development in the sample prior to mowing. These data would have been useful since the number of thrips collected in orchard R was very small (mowed n=22; control n=6) which may have effected the outcome of the test.

Dandelion Samples

Although there were dandelions present in the sample orchards their flowering occurred approximately 2 weeks after the time of full bloom of the apple trees in each of the three orchards. The dandelions did not carpet the orchard with blooms, as they do in some years. The distribution of dandelions was clumped with a few dandelion flowers in scattered patchs throughout the orchard. When the plots were established, the number of dandelion plants in the ground cover was estimated and deemed sufficient to allow for a 'good' dandelion bloom, but this did not occur. Only 38 thrips were recovered from 840 dandelion flowers, and of these 35 (92%) occurred in samples from orchard H, in which both plots were mowed.

The numbers of thrips found in the dandelions were substantially lower than in the apple flowers. In most cases, once the apple flowers start to bloom, there are several magnitudes more apple flowers in the orchard than dandelion flowers. The thrips may be finding the apple flowers more often, simply because there are more of them. Thrips may not readily switch from an early blooming host to another unless forced to do so. Since the apples bloomed first the thrips may have been established in the trees and may not have moved down into the ground cover when the dandelions became suitable. It has been suggested that dandelions may not be a preferred host for thrips because the flower withers rapidly, which may trap the thrips inside the corolla (Kirk 1984b). There may also have been few thrips in some dandelions due to the presence of unidentified dipteran larvae found in 6.25% (range 0–25%) of the dandelion samples. This dipteran may have disturbed the thrips, causing them to seek alternate hosts, or even preyed upon them. Recovery of thrips from the dandelions was apparently satisfactory as inspection of flowers with a dissecting microscope after the extraction process failed to reveal any remaining thrips.

Sticky Trap Samples

There were considerable variations in the numbers of thrips caught in upper and lower sticky traps, and in the two plots in each orchard, but were not strongly related to mowing. In all cases where there was a difference in the numbers of thrips caught between the upper and lower traps in the same trap tree, the upper trap always caught significantly more thrips.

The average numbers of thrips caught per trap per day on sticky traps for various intervals during the sampling period are shown in Figures 5-7. Except for three predatory thrips, all of the thrips caught in the sticky traps were adult *F. occidentalis*. There was a mixture of colour morphs collected on the sticky traps.

To determine if there were positional effects of trap tree position on sticky trap catches, the data for each position were pooled for the entire sampling season and analyzed using analysis of variance. For each plot the effect of trap tree position on the upper, lower and the combined upper and lower traps catches per trap were analyzed. There were no significant differences between trap tree position at any trap height, for all three orchards. Student t tests were performed using transformed data {ln(x+1)} to analyze the effect of trap height on the numbers of thrips caught per trap for each trap tree for the entire sampling season. In orchard R, there was no significant difference between upper and lower trap catchs for three of the four trap tree positions in each plot. Trap tree four, in the mowed plot, had significantly more thrips caught in the upper than lower trap ($p=0.022$). In the control plot significantly more thrips were caught in the upper trap than in the lower trap of trap tree position two ($p=0.0079$). In orchard Ha, all trap tree postions for both plots caught significantly more thrips in the upper than lower traps. In orchard H, the north plots' trap tree position two caught significantly more thrips in the upper than lower trap ($p=0.035$). In the south plot, the sticky traps of two trap tree positions, one and three, caught significantly more thrips in the upper traps than the lower traps ($p=0.057$, $p=0.039$; respectively). The location of these trap trees did not have physical characteristics which might explain their differences from the other trap trees.

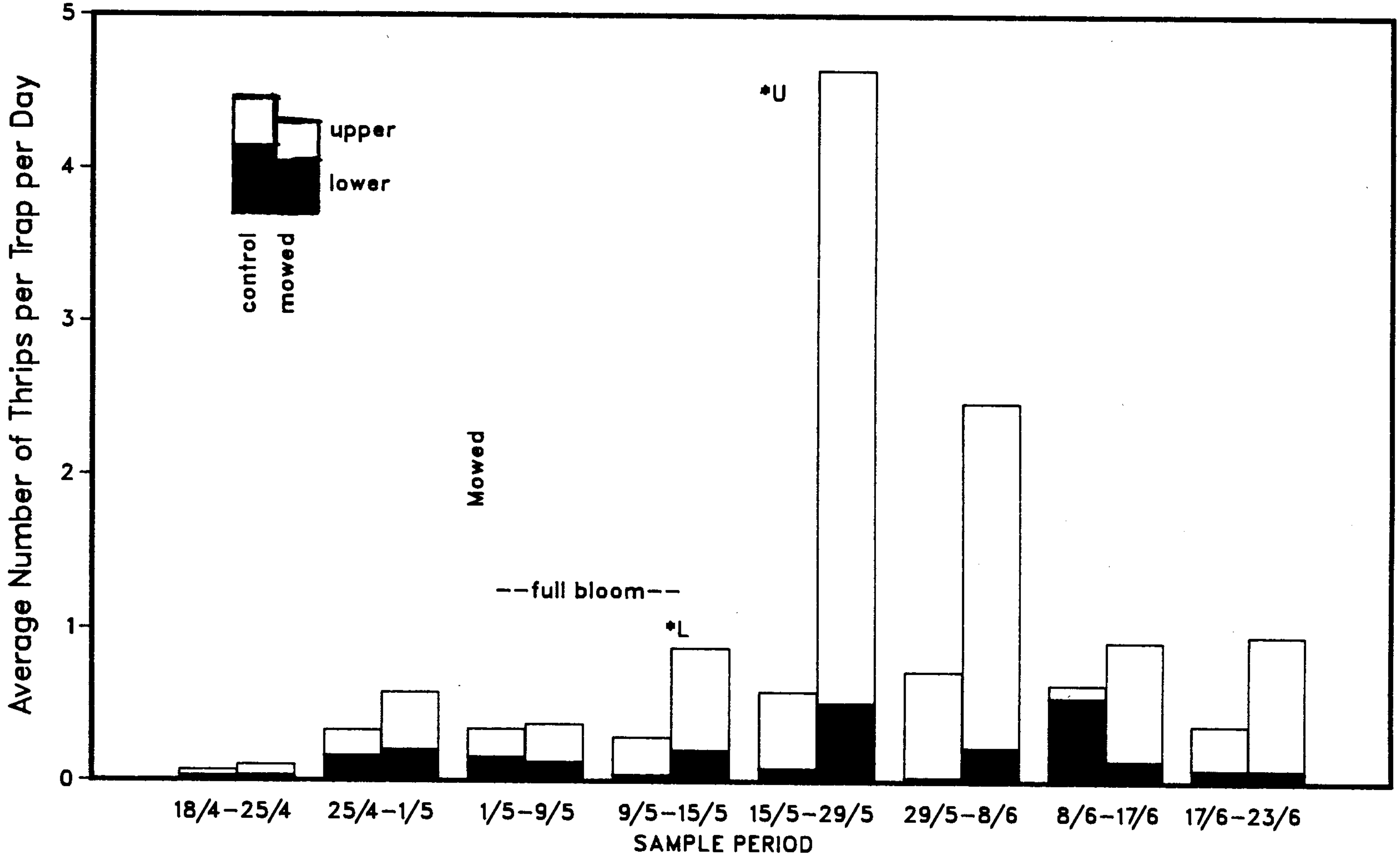

Figure 5. The average number of thrips caught per trap per day on sticky traps in orchard R. Asterisks indicate significant differences (t test, $p=0.05$) between numbers of thrips caught in mowed and unmowed plots for lower (L) and upper (U) data for lower and upper traps.

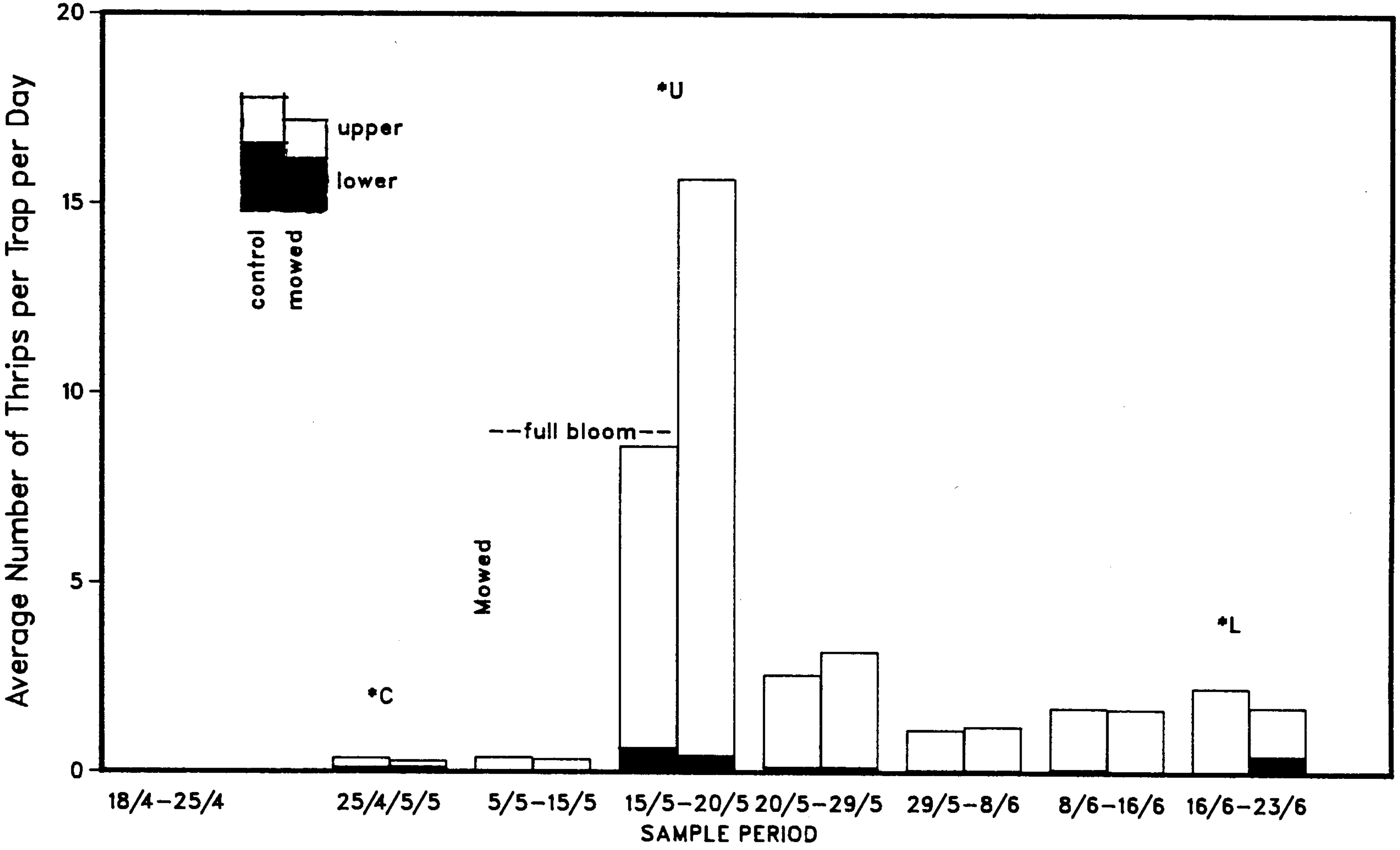

Figure 6. The average number of thrips caught per trap per day on sticky traps in orchard Ha. Asterisks indicate significant differences (t test, $p = 0.05$) between numbers of thrips caught in mowed and unmowed plots for lower (L), upper (U) and combined (C) data for lower and upper traps.

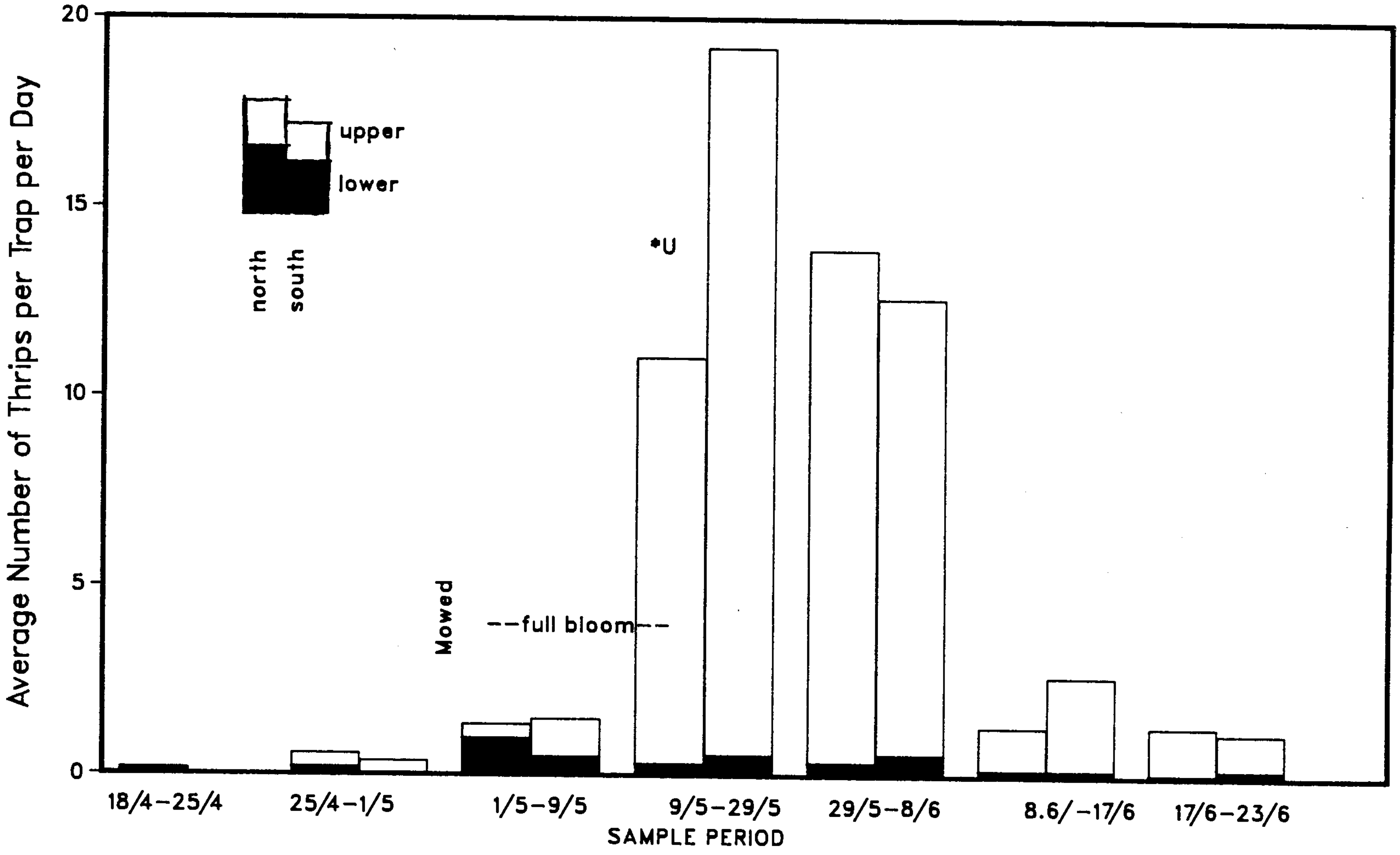

Figure 7. The average number of thrips caught per trap per day on sticky traps in orchard H. Asterisks indicate significant differences (t test, $p=0.05$) between numbers of thrips caught in mowed and unmowed plots for upper (U) data for lower and upper traps.

In order to determine if mowing the cover crop had an effect on the number of thrips caught in sticky traps, the number of thrips caught in the mowed and unmowed plots were compared by t test using transformed {ln(x+1)} catch per trap per day data for the first complete sampling period following the time of mowing. In orchard R there was no significant difference between the the treatments for catches in the upper traps (p=0.22), but significantly more thrips were caught in lower traps in the mowed plot than in the unmowed plot (p=0.033). In orchard Ha there were significantly greater numbers of thrips caught in the upper traps in mowed compared with unmowed plots (p=0.029), but no difference between the treatments was detected in the lower traps (p=0.76). In orchard H, where both plots were mowed, significantly more thrips were caught in the upper traps of the south than of the north plot (p=0.0082), but there was no difference between the thrips catches in the two plots on the lower traps (p=0.33). The differences may be the result of natural variation within the thrips population, edge effects (the southern plot of orchard H was closer to uncultivated land and the cherry block, which may also have been a source of thrips) or a sampling artifact. For all other sample periods, the trap catches for both plots were also analyzed. In orchard R, all trap catchs were not significantly different from each other. In orchard Ha, the combined upper and lower trap catches in the sample period just prior to mowing were significantly higher in the control plot than in the 'mowed' plot ($p \leq 0.05$). Since mowing had not occurred at this time, this difference is the result of other factors. For the last sample period, the mowed plot had significanty more thrips collected in the lower traps than the control plot (p=0.028). In orchard H, there were no significant differences between the numbers of thrips caught per trap per day in the sample periods not already mentioned above.

The old sticky trap paper caught an average of 15.17 ± 8.86 thrips and the new sticky trap paper caught an average of 7.67 ± 3.27 thrips. Although the difference between the two types of papers used to construct the sticky traps was barely insignificant (t test: calculated t=2.142, critical t=2.228 p<0.05), it was substantial (Table 2). Clearly, the use of different types of paper for constructing sticky traps within an experiment should be avoided, and the careful selection of paper can maximize the efficacy of traps.

June-drop Samples

Pansy spot damage on aborted apples ranged from 0% (orchard Ha, both plots) to 11.66% in the unmowed plot of orchard R (Table 2). Orchard Ha had a very small fruit set and also a small number of June-drops. Orchard H had a very heavy June-drop, and because of the number of apples aborted only 5 trees were sampled (approximately 2000 aborted apples from orchard H were examined). The percentage of retained apples with pansy spots ranged from 0% in orchard H, to 18.75% in the mowed plot of orchard R. The majority of the aborted apples examined had no physical sign as to the reason for abortion. Aborted apples with pansy spots typically had two or more spots per fruit (Table 2).

There was no significant difference between the level of damage on the tree and the damage in the aborted fruits (Mann-Whitney test p=0.2963). Therefore it did not appear that the tree was selectively aborting the thrips-damaged apples.

Harvest Samples

Differences in the amount of damage in mowed and unmowed plots are not apparent in the data for either of the two orchards in which this treatment was executed (Table 2). In orchard R, 17 of 4389 apples (0.39%) from the unmowed plot, and 14 of 4705 apples (0.30%) from the mowed plot had pansy spots. The mean numbers of pansy spots per damaged apple were 2.2 and 5.1 for apples from the unmowed and mowed plots, respectively (Table 2). In orchard Ha, 10 of 664 (1.5%) and 31 of 1916 (1.6%) of apples from the

Table 2. Pansy Spot Damage on Fruit at 'June-drop' and at Harvest.

Orchard and Variety	Treatment	JUNE DROP					HARVEST		
		Aborted Fruit		Retained Fruit					
		N	%	N	%	spots per damaged fruit	N	%	spots per damaged fruit
R (Spartan)	mowed	540	4.6	64	18.8	2.4	4705	0.30	5.1
	unmowed	352	11.4	64	17.2	2.7	4389	0.39	2.2
Ha (Spartan)	mowed	41	0.0	60	1.7	-	1916	1.6	2.7
	unmowed	4	0.0	60	5.0	-	664	1.5	2.6
H (McIntosh)	mowed (N)	1974	0.61	20	0.0	2.7	1300	7.3	5.5
	mowed (S)						1518	8.0	4.0

unmowed and mowed plots, respectively, had pansy spots. Mean numbers of pansy spots were 2.6 and 2.7 per damaged apple from the unmowed and mowed plots, respectively (Table 2). In orchard H, where both plots were mowed, 95 of 1300 (7.3%) and 122 of 1518 (8.0%) of apples from the two plots had pansy spots, and the respective mean numbers of pansy spots per damaged apple were 5.5 and 4.0 (Table 2).

The levels of pansy spot in the various orchards at harvest do not agree well with the levels estimated in retained fruit at June-drop (Table 2). This unexpected result most likely indicates that the numbers of retained fruits sampled at June-drop were too small to provide an accurate estimate of the level of pansy spot present at that time.

The majority of the pansy spots observed in this experiment were very small and probably would not cause the fruit to be downgraded unless there was also a larger pansy spot on that apple (Figure 8-10).

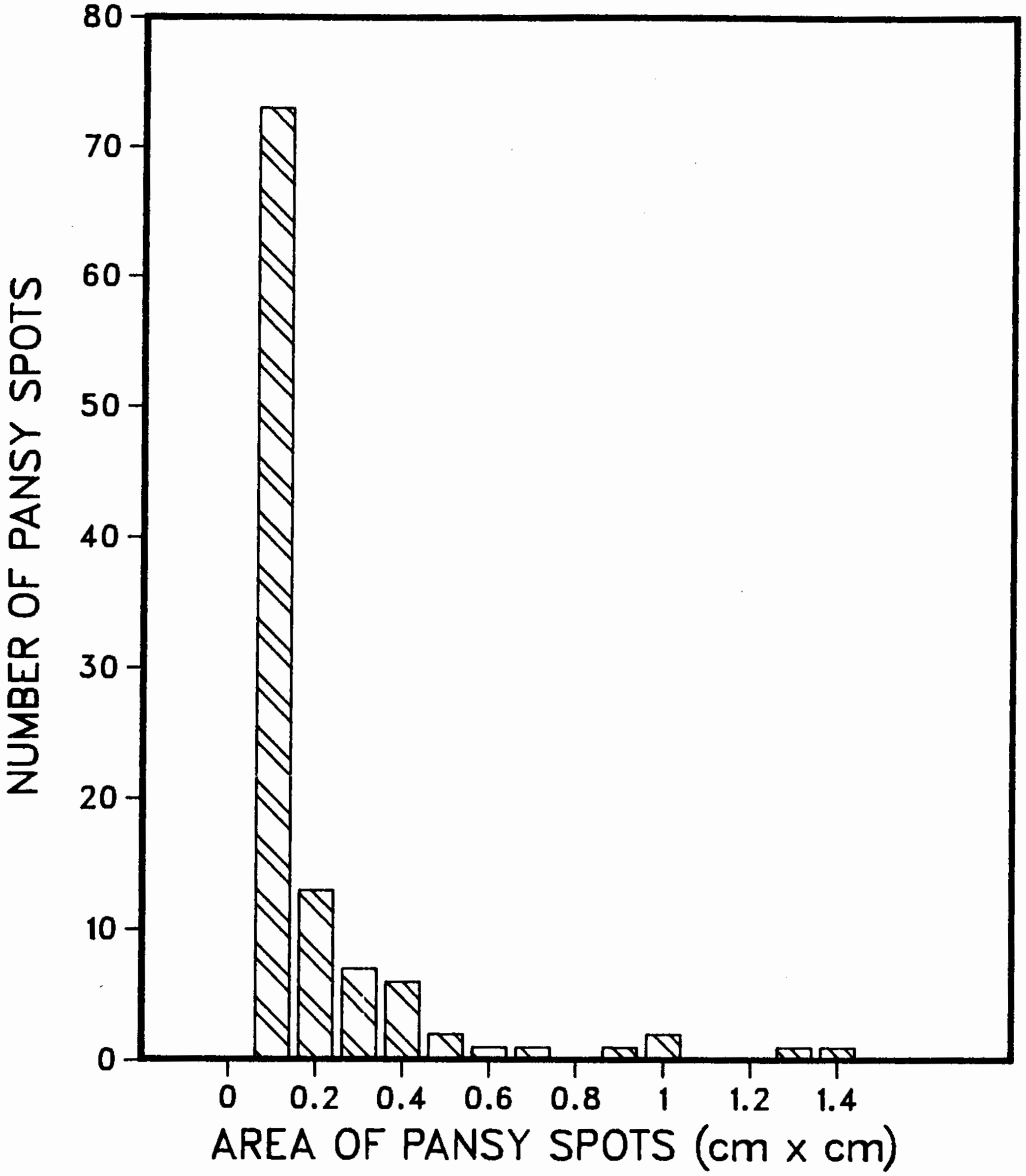

Figure 8. The size distribution of pansy spots on Spartan apples in orchard R.

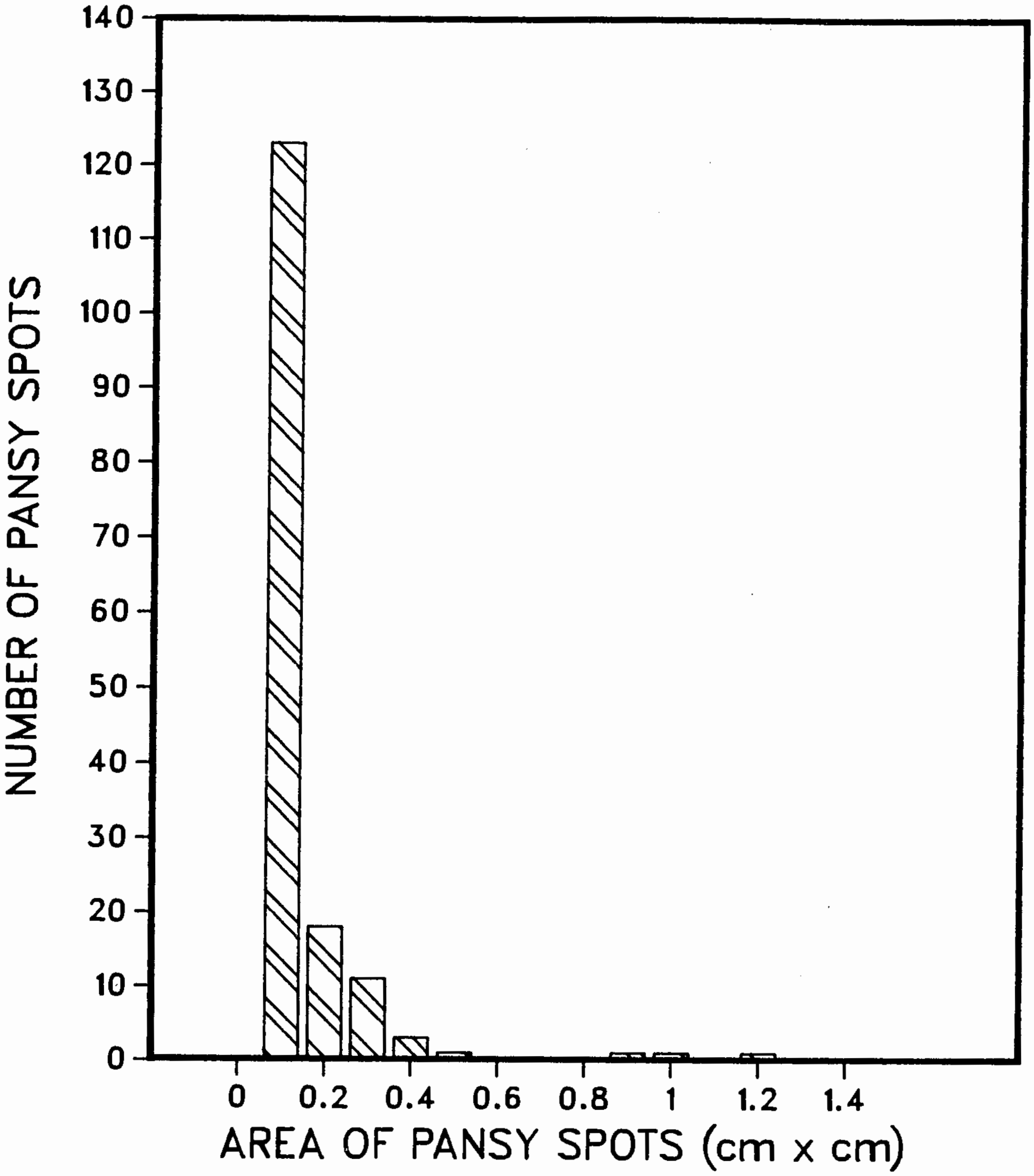

Figure 9. The size distribution of pansy spots on Spartan apples in orchard Ha.

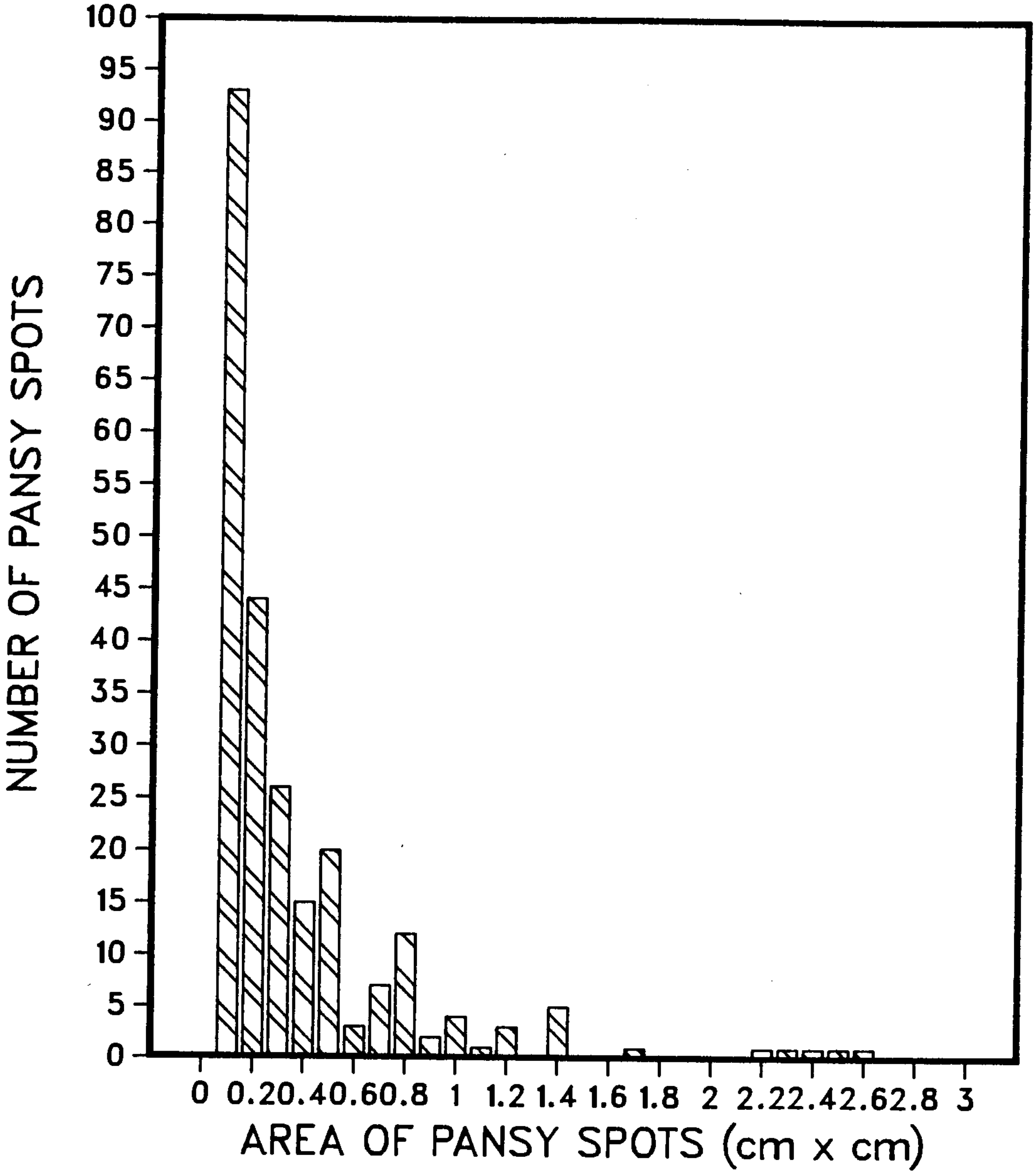

Figure 10. The size distribution of pansy spots on McIntosh apples in orchard H.

CHAPTER VII

DISCUSSION

In general, the thrips populations were low for the duration of this experiment, except in orchard H where both plots were mowed. Prior to the start of sampling I observed a substantial thrips population in orchard Ha, yet only 11 thrips were collected from the blossom clusters during the entire sampling period. Perhaps the thrips I observed when establishing the plots emigrated from the orchard before the apple blooms opened. The management practices of the orchardist may also have reduced the number of thrips in this orchard, although very little work is performed in orchards prior to bloom.

The increase in thrips collected during the bloom period in orchards R and H, may have resulted from the migration of thrips into the orchard or the migration of thrips within the orchard. Since few thrips were recovered from the dandelions even in the unmowed plots, it seems unlikely that the thrips moved from them into the trees. There were other flowering plants {white clover (*Trifolium repens*), field bindweed (*Convolvulus arvensis*), and commen milkweed (*Asclepias syriaca*)} in the covercrop, but they did not bloom before the apples. It is possible that the thrips were in the grass and flowering plants even though they were not blooming. The increase associated with apple blossom opening may also have been due to the late emergence of overwintering female *F. occidentalis*. Lewis (1973) reports that thrips emerge in the spring, but no timeframe or temperature threshold is given. The increase may have been due to newly emerged adults. There were no nymphs found in the cluster samples prior to 25 April, so if the increase was due to a new generation of thrips, they must have originated from host plants other than apple. Finally, the increase in thrips when the flowers opened may have been due to immigration of thrips into the plots. All of the plots were near uncultivated land and peach and cherry orchards (they bloom before apples), which may have been a source of thrips.

Research should be conducted to determine the source of these thrips in the apple flowers. The movement of thrips could be documented using a mark recapture experiment, but since these experiments would have relatively low recapture rates, thousands of thrips must be released. Alternatively, since thrips are reported to carry pollen on their bodies (Morison 1957; Lewis 1973), the source of the pollen could be analyzed for each captured thrips using techniques similar to those used for honey bees (Free 1968), and thus provide evidence of the previous location of the thrips.

Although there was an increase in the thrips populations in the flower clusters it does not appear that this is the result of mowing. It was unfortunate that the majority of the dandelions bloomed after the apples and very few thrips were present in the sampled flowers. Since few dandelions were blooming prior to the apple bloom, I feel that they were not competing with the apples for pollinators and therefore the orchardists probably did not need to mow. In some orchards in some years, however, dandelions may represent a threat to pollination and perhaps serve as a source of thrips that damage apples. Dandelions invade the covercrop and therefore the numbers of dandelions in an orchard is dependent upon location, cultural practices, age and competitive vigour of the covercrop. The degree of interaction between dandelions and apple trees depends upon the dandelion population in the cover crop, their time of bloom, and the movement patterns of thrips in the various types of orchard vegetation. More research is needed to determine the role and interactions of these various factors.

The numbers of thrips caught on the sticky traps did not differ significantly among the four trap trees within any of the plots. When the numbers of thrips caught on the upper traps were compared to those on the lower traps for the entire sampling season there were no clear trends. The upper traps did catch more thrips in the sample periods after full bloom. The upper traps were probably sampling the thrips population above the orchard canopy. Cylinder shaped traps were selected because they are more efficient in capturing small wind borne particles than are flat surfaces (Gregory 1951; Lewis 1959). Insects which are less than 0.635 cm long behave like inert particles during capture on impaction traps in wind speeds of 3.2 to 16 kph (Taylor 1962). Once the trees begin to leaf out, the lower traps are affected less by the wind, and thrips movement is substantially an active process of the thrips itself. The upper traps were located above the canopy so therefore they were affected by air turbulence and drag created when the airstream passed over the orchard. It is difficult to estimate without data from a wind anemometer the effect of wind on the upper and lower trap catches. The Similkameen Valley is renowned for its constant winds. During a study by Chilton, winds exceeded 11 kph 43.8% of the time, and there were no days when the wind did not exceed 11 kph. (R. Chilton[15], personal communication).

The blossom cluster samples and the sticky trap catches were used as techniques for monitoring thrips populations. The blossom clusters estimated thrips populations on the host plant and the sticky traps estimated populations above and around the host plant. Both techniques indicate that thrips populations in the orchards were initially low and then increased as the apple flowers opened. The increased populations of thrips were detected in apple blossoms before they were detected on the sticky traps. Whether the time of increase of thrips caught on sticky traps indicates the departure of thrips from apple blossoms, or the influx of an additional population to the orchard is not clear.

There are several methods of extracting thrips from plant material. Haley (1976) recommends the use of Berlese funnels for 12 hours to remove the thrips from the apple blossoms. Since data on individual flower clusters were required for this experiment, this method was rejected as it was too time consuming. Other techniques involve the combined use of repellents {turpentine (Evans 1933), isobutyl ketone (Madsen and Jack 1966)} and light to extract the thrips. This approach was rejected due to a certain amount of mortality to the thrips while still in the blossom, and thus the failure of these thrips to be extracted. Tippins

---

[15] R.R.#1, Site 148, Comp. 10, Comox, B.C.

and Hyche (1955) agitated thrips-containing foliage in a sodium chloride solution. The thrips were then collected from the bottom of the container. Taylor and Smith (1955) agitated foliage in a dilute detergent solution. LePelley (1942) agitated blooms in ethanol and then collected the thrips. Bullock (1963) suggested a two solvent agitation system. He agitated with 70% ethanol, seived onto a nylon mesh, washed with water to remove the thrips, added benzene, then overflowed the beaker by adding water. The thrips were washed into a petri dish with the benzene. Burgess and Shamiyeh (1971) stirred rose blooms in a solution of 70% isopropyl alcohol and 2 to 3 ml of detergent for 60 seconds. The thrips were allowed to settle out. The technique removed 100% of thrips in the first extraction, as long as the rose petals were only one layer thick in the stirring dish. Although the techniques by Bullock and Burgess-Shamiyeh are very efficient in extracting all the thrips present in samples that contain a large amount of organic material, they are very labour intensive. When all the techniques (repellency, dislodgement and agitation) were compared, the dilute detergent extraction system was determined to be the most suitable (90% efficient), followed by an ethanol wash (70% efficient) (Taylor and Smith 1955; Ota 1968). Based upon this literature I selected a detergent agitation technique for recovery of the thrips from the flower samples.

To determine the efficiency of the extraction technique, every tenth sample was further processed by putting the soapy water (from which thrips had been removed with a pipet) through a funnel lined with a filter paper. As soon as filtration was complete, the filter paper was examined with a dissecting microscope for the presence of thrips. The blossom, after it had been rinsed, was examined with a dissecting microscope to determine if all the thrips had been removed by the agitation process. Any thrips collected from these further processing steps were not included in the blossom cluster or dandelion data. In all the blossoms examined by further processing (apples and dandelions) no thrips were remaining within the flower after the agitation step. Thrips were observed on the filter paper in 13 of

228 of the blossom cluster samples examined and 4 of 48 dandelion samples. The majority of thrips collected by this further processing were nymphs. As the numbers of thrips increased in the cluster samples the efficiency of the extraction decreased. I recommend that the processing of flower samples include the filtration step.

Although the blossom clusters were very labour intensive to process (2.25 minutes per cluster), they provide an estimate of the population which is causing the damage. The processing time for the flower clusters could be reduced by extracting the thrips using a Berlese funnel (Haley 1976). In order to use a Berlese funnel efficiently for extracting thrips, numerous blossom clusters would have to be grouped as one sample and the funnel must be sealed tightly to prevent the thrips from escaping. The sticky traps are easier to count (an orchardist can do this himself with little training), but are messy to use and do not estimate the same population of thrips as that sampled in the blossom clusters. If sticky traps were to be used as a monitoring technique for thrips, I would suggest that more research on trap location is needed before the traps can be used as a monitoring tool. The sticky traps caught other insect pest, such as *Campylomma*, aphids and wood borers, which may aid the orchardist in identifying other potential insect problems.

When the levels of damage are compared for the 'June-drop' sample and the harvest sample, an inverse relationship is suggested, particularly for orchards R and H (Table 2). This is improbable and difficult to explain. In orchard R there was 11.66% damage in the unmowed plot at 'June-drop' and only 0.39% damage at harvest. The same trend is observed in the mowed plot, 18.75% damage at 'June-drop' and 0.3% damage at harvest. If this difference is not explained by an inaccurate estimate of damage in retained fruit at 'June-drop', due to sample size, then the damaged apples must have been removed from the tree. Orchard R was thinned by manual labour, but the workers were not instructed to remove damaged fruit. An experienced worker may do so on his own accord, but I have no way of determining if this occurred. The tree might abort the damaged fruit at some point after 'June-drop'; since I did not observe large aborted fruit on the floor of the orchard, I do not think this occurred. The variety Spartan was developed by crossing McIntosh and Newtown varieties (R. MacDonald[16], personal communication). Since both of these varieties are susceptible it seems unlikely that the offspring of a cross between the two of them would be able to 'out grow' thrips damage. Therefore it is unlikely that the lower level of damage in orchard R at harvest was due to the fruit 'out growing' the pansy spots. In orchard H, which had the lowest levels of damage at 'June-drop' and the highest at harvest, the small sample size used to estimate damage in retained fruit at time of 'June-drop' may have failed to estimate the true level of damage present. If the discrepancy is not due to the sample size, then it could be the result of additional damage after 'June-drop'. The literature indicates that thrips enter the newly opened flowers and leave as soon as the flower becomes unattractive (Bailey 1938). Therefore I would not expect the fruit to be attractive to flower thrips. Research should be conducted on the exact time of thrips damage which results in the pansy spot blemishs on apples. If *F. occidentalis* can cause pansy spot blemishs by ovipositing into apples after 'June-drop', then the periodic mowing of the covercrop to allow easier access to the orchard may be increasing thrips damage. Other species of thrips should also be evaluated to determine if they can cause pansy spots on apples. If a grass dwelling thrips can cause pansy spots, mowing the covercrop could affect the level of damage. As there is a decrease in damage in one orchard, an increase in another and the third remained approximately the same, I can not comment on the reason for this reversal in the damage levels from 'June-drop' to harvest.

The majority of the pansy spots recorded at harvest were very small. I can not calculate the percentage of apples which would have pansy spots large enough to be culled. The grading process is very subjective. From personal observation, very little damage is tolerated on the grading line. Even apples with small pansy spots are made into apple juice.

---

[16] Agriculture Canada, Summerland Research Station, Summerland, B.C.

The small black dot type of damage, due to thrips, usually is not downgraded. These spots are almost impossible to detect when the fruit is passing on a conveyer belt. The damage levels reported in this experiment are based on the total amount of damage caused by the western flower thrips. The growers may have actually experienced a lower level of cullage. If the packinghouse grades according to standards established, most of the apples with pansy spots would not be culled, but downgraded. Downgrading reduces the economic returns to the grower, but culling returns very little money to the grower. Since I can not determine the percentage of the damaged apples which were actually culled, I can not determine an economic threshold from my data.

Since my data did not indicate whether mowing effected thrips damage in apple orchards, I can not offer a recommendation to the orchardist whether mowing should be conducted before bloom.

Even though, in this experiment, the damage levels are low, western flower thrips can produce very high levels of damage, so a precise sampling system should be developed for this pest. Research should also be conducted into adapting the computer model REDAPOL for use in British Columbia. Research should be conducted into the use of biological control agents, especially those that are suitable for the interior British Columbia climate and that can be commerically reared and released, such as *Amblyseius cucumeris, Oruis tristicolor, Haplothrips niger* and *Leptothrips mali.* Research should also be conducted on the biology of the native predators, pathogens and parasites of the western flower thrips. The majority of information on these native biological control agents is in the form of short notes and one line sentences in scientific articles on other subjects. The physiological effects of thrips oviposition and feeding damage on the fruit should be investigated, to determine why some varieties are able to "out grow" the damage caused by the western flower thrips. Also the possible relationship between the pansy spots and the tomato spotted wilt virus should be investigated. Although the western flower thrips is a fairly low profile insect pest for most orchards, this research is necessary for a complete integrated control program for all orchard pests. Finally, the importance of the western flower thrips may slide further into the background if new, more serious insect pests arrive in British Columbia, *e.g.* the apple maggot. If, or when, these insects arrive in the commerical apple growing regions of British Columbia, the use of biological control agents for the control of other insect pests may have to be abandoned as the result of the use of insecticides to control these new pests. Research should be conducted prior to the arrival of these new threats to the apple industry on how to integrate programs for their control into already existing programs for other pests.

CHAPTER VIII

REFERENCES

Adams, R.W. 1987. **Handbook for Pesticide Applicators and Dispensers.** British Columbia Ministry of Environment and Parks, Pesticide Control Branch, Victoria, B.C. 248 pp. ISBN 0-7726-0610-2

Allen, W.R. and A.B. Broadbent. 1986. Transmission of tomato spotted wilt virus in Ontario greenhouses by *Frankliniella occidentalis.* Can. J. Plant Path. 8:33-38.

Altieri, M. 1981. Crop-weed-insect interactions and the development of pest-stable cropping systems. pp.459-466 *in* Pest, Pathogens and Vegetation. J.M. Thresh (ED.) Pitman, London.

Altieri, M.A. and L.L. Schmidt. 1986. Cover crops affect insect and spider populations. California Agriculture 40:15-17.

Anonymous. 1981a. **Pesticide Pollinator Interactions.** National Research Council Publication NRCC No. 18471.

Anonymous. 1981b. Citrus thrips showing resistance to dimethoate. Citrograph 66(10):247.

Anonymous. 1987. **Tree Fruit Production Guide for Interior Districts, 1987.** ISSN 0705-470X British Columbian Ministry of Agriculture and Fisheries, Victoria, B.C.

Atkinson, D. and G.C. White. 1981. The effects of weeds and weed control on temperate fruit orchards and their environment. pp. 415-428 *in* Pests, Pathogens and Vegetation. J.M. Thresh (ed.) Pitman, London.

Atkinson, D. and R.F. Herbert. 1979. A review of long term effects of herbicides: effects on the soil with particular reference to orchard crops. Ann. Appl. Biol. 91:125-129.

Bailey, S.F.. 1933. A contribution to the knowledge of the western flower thrips, *Frankliniella californica* (Moulton). J. Econ. Ent. 26:836-840.

Bailey, S.F. 1935. Thrips as vectors of plant diseases. J. Econ. Ent. 28:856-863.

Bailey. S.F. 1938. Thrips of economic importance in California. Univ. of California Agricultural Exp. Station Circ. 346:24.

Bailey, S.F. 1940. The black hunter, *Leptothrips mali* Fitch.. J. Econ. Ent. 33:539-544.

Bartlett, P.W. 1988. Western flower thrips *Frankliniella occidentalis.* Min. of Agriculture, Fisheries and Food, Harpenden Laboratory, Harpenden, Hertfordshire, England. Plant Pest Notice Jan. 1988 ref PPH 1291.

Beshear, R.J. 1983. New records of thrips in Georgia (Thysanoptera : Terebrantia : Tubulifera). J. Georgia Ent. Soc. 18:342-344.

Binns, E.S., R.A. Hall and R.J.J. Pickford. 1982. *Thrips tabaci* Lind. (Thysanoptera : Thripidae) distribution and behavior on glasshouse cucumbers in relation to chemical and integrated control. Ent. Mon. Mag. 118:55-68

Bohmont, B.L. 1983. **The New Pesticide User's Guide.** Reston Publ. Co. Ltd., Reston, Virginia. 452 pp.

Boivin, G. and R.K. Stewart. 1982. Identification and evaluation of damage to McIntosh apples by phytophagous Mirids (Hemiptera : Miridae) in Southwestern Quebec. Can. Ent. 114:1037-1045.

Borden, A.D.. 1915. The mouthparts of the Thysanoptera and the relation of thrips to the non-setting of certain fruits and seeds. J. Econ. Ent. 8:354-360.

Boyce, H.R. 1955. Note on injury to tree fruits by *F. tritici* (Fitch.). Can. Ent. 87:238-239.

Broadbent, A.B. 1986. Growers seek control measure for western flower thrips. Greenhouse Canada, June 1986:6,8.

Broadbent, A.B., W.R. Allen and R.G. Footitt. 1987. The association of *Frankliniella occidentalis* (Pergande) (Thysanoptera : Thripidae) with greenhouse crops and tomato spotted wilt virus in Ontario. Can. Ent. 119(5):501-503.

Bryan, D.E. and R.F. Smith. 1956. The *Frankliniella occidentalis* (Pergande) complex in California (Thysanoptera : Thripidae). Univ. California Pub. Ent. 10(6):359-410.

Buchel, K.H. and G.M. Holmwood. 1983. **Chemistry of Pesiticides.** John Wiley and Son Publ., New York. 518 pp.

Bullock, J.A. 1963. Extraction of Thysanoptera from samples of foliage. J. Econ. Ent. 56:612-614.

Burgess, E.E. and N.B. Shamiyeh. 1971. An improved method of flower thrips extraction from rose flowers (*Frankliniella tritici*; Thysanoptera, Thripidae). J. Econ. Ent. 64:545-546.

Carl, K.P. 1975. An *Entomophtora* sp. (Enthomophthorales : Entomophthoraceae) pathogenic to *Thrips* spp. (Thysanoptera : Thripidae) and its potential as a biological control agent in glasshouses. Entomophaga 20:381-388.

Chapman, P.J. and G.A. Catlin. 1976. Growth stages in fruit trees from dormant to fruit set. New York's Food and Life Sciences Bulletin 58:1-12.

Chalfant, R.B. and J.R. Young. 1984. Management of insect pests of broccoli, cowpeas, spinach, tomatoes and peanuts with chemigation by insecticides in oils, and reduction of watermelon virus 2 by chemigation oil. J. Econ. Ent. 77:1323-1326.

Childs, L.F. 1927. Two species of thrips injurious to apples in the Pacific Northwest. J. Econ. Ent. 20:805-809.

Cremlyn, R. 1978. **Pesticides : Preparation and Mode of Action.** John Wiley and Son Publ., Salisbury, U.K. 240 pp.

DeGrandi-Hoffman, G., R. Hoopingarner and R. Pulcer. 1987. REDAPOL : pollination and fruit-set prediction model for 'delicious' apples. Envir. Ent. 16:309-318.

DeGrandi-Hoffman, G., I. Terry and R.T. Huber. 1988. Incorporating fruit set estimates with thrips management to create a decision support system for apples. HortScience 23:571-574.

Eastop, V.F. 1981. Wild hosts of aphid pests. pp. 285-298 *in* Pests, Pathogens and Vegetation. J.M. Thresh (ED.) Pitman, London.

Edwards, C.A. and J.R. Lofty. 1978. The influence of arthropods and earthworms upon root growth of direct drilled cereals. J. Appl. Ecol. 15: 789-796.

Evans, J.W. 1933. A simple method of collecting thrips and other insects from blossom. Bull. Ent. Res. 24:349-350.

Free, J.B. 1964. Comparison of the importance of insect and wind pollination of apple trees. Nature, London 201:726.

Free, J.B. 1968. Dandelion as a competitor to fruit trees for bee visits. J. Appl. Ecol. 5:169-178.

Free, J.B. 1970. **Insect Pollination of Crops.** Academic Press (London) Ltd..

Free, J.B., J.A. Pickett, A.W. Ferguson, J.R. Simpkins and M.C. Smith. 1985. Repelling foraging honeybees with alarm pheromones. J. Agric. Sci. 105(2):255-260.

Frogatt, W.W. 1931. Thrips. The present garden pest. Aust. Beekeeper 33(5):130-131.

Gillespie, D.R. *in press* Biological control of thrips (Thysanoptera : Thripidae) on greenhouse cucumber by *Amblyseius cucumeris.* Entomphaga.

Glick, P.A. 1939. The distribution of insects, spiders and mites in the air. U.S.D.A. Tech. Bull. 673:1-150.

Gregory, P.H. 1951. Deposition of air-borne *Lycopodium* spores on cylinders. Ann. Appl. Biol. 38:357-376.

Grivanov, K.P. 1939. Deep ploughing instead of burning the stubble for the control of the wheat thrips (*Haplothrips tritici* Kurd.). Rev. Appl. Ent. (A) 28:69-70.

Grout, T.G. and J.G. Morse. 1986. Insect growth regulators: effects on citrus thrips (Thysanoptera : Thripidae). Can. Ent. 118:389-392.

Haley, S. 1976. **Apple Pest Management in the North Okanagan Valley, British Columbia : A Feasibility Study.** Masters of Pest Management Thesis, Simon Fraser University, Burnaby, B.C., Department of Biology.

Hall, R.A. 1981. *Verticillium lecanii* as a microbial insecticide against aphids and scales. pp. 483-498. *In* Microbial Control of Plant Pests and Diseases. H.D. Burges (ed.). London Academic Press.

Hassall, K.A. 1982. **The Chemistry of Pesticides : Their Metabolism, Mode of Action and Uses in Crop Protection.** MacMillian Press Ltd., London. 372 pp.

Hogue, E.J. 1986. Orchard Floor Vegetation Management Options : Orchard Weedspraying. British Columbia Ministry of Agriculture and Fisheries, Victoria, B.C. 20 pp.

Hopkins, A.R. and R.F. Moore. 1982. Control of thrips spp., 1979, 1980 and 1981 (*Frankliniella tritici, F. fusca, Thrips tabaci*). Ent. Soc. Am. Insecticides and Acaricide Tests 7:158.

Howlett, F.M. 1914. A trap for thrips. J. Econ. Ent. 9:21-23.

Johnson, C.G. 1969. **Migration and Dispersal of Insects by Flight.** Methuen, London 763 pp.

Killian, J.C. and J.C. Meyer. 1984. Effect of orchard weed management on catfacing damage to peaches in North America. J. Econ. Ent. 77(6):1596-1600.

Kirk, W.D.J. 1984a. Ecologically selective coloured traps. Ecol. Ent. 9:35-41.

Kirk, W.D.J. 1984b. Ecological studies on *Thrips imaginis* Bagnall (Thysanoptera) in flowers of *Echium plantagineum* L. in Australia. Australian J. Ecol. 9:9-18.

Kirk, W.D.J. 1984c. Pollen-feeding in thrips (Insecta : Thysanoptera). J. Zool., Lond. 204:107-117.

Kirk, W.D.J. 1985a. Pollen-feeding and the host specificity and fecundity of flower thrips. Ecol. Ent. 10(3):281-289.

Kirk, W.D.J. 1985b. Effect of some floral scents on host finding by thrips (Insecta : Thysanoptera). J. Chem. Ecol. 11(1):35-43.

Kolobova, A.N. 1926. *Stenothrips graninum* Uzel. Rev. Appl. Ent. (A) 14:606-607.

Kremer, J.C. 1950. The dandelion and its influence on bee behavior during fruit blossoming period. Proc. Am. Soc. Hort. 55:140-146.

Krombein, K.V. 1958. Miscellaneous prey records of solitary wasps III (Hymenoptera : Aculata). Proc. Biol. Sco. Wash. 71:21-26.

Kurdjumov, N.V. 1913. The more important species injurious to grain crops in Middle and South Russia. Rev. Appl. Ent. (A) 2:170-173.

Kumar, N. Suresh and T.N. Ananthakrishnan. 1984. Predator thrips interactions with reference to *Orius maxidentex* and *Carayonocoris indicus* (Anthrocoridae : Heteroptera). Indian Natl. Sci. Acad. Part B. Biol. Sci. 50(2):139-145.

Laster, M.L., R.S. Baker and W.F. Kitten. 1984. Effects of dinoseb and dinoseb+MSMA on arthropod populations in cotton fields. J. Econ. Ent. 77:741-743.

Lee, M.L. 1986. Cost Competitiveness of Apple Production in British Columbia versus Washington State. Dept. of Agricultural Economics, Univ. of B.C. Sept. 1986.

LePelley, R.H. 1942. A method of sampling thrips populations. Bull. Ent. Res. 33:147-148.

Lewis, T. 1959. A comparison of water traps, cylindrical sticky traps and suction traps for sampling Thysanoptera populations at different levels. Ent. Exp. Appl. 2:204-215.

Lewis, T. 1964. The weather and mass flights of Thysanoptera. Ann. Appl. Biol. 53:165-170.

Lewis, T. 1965. The species, aerial density and sexual maturity of Thysanoptera caught in mass flights. Ann. Appl. Biol. 55:219-225.

Lewis, T. 1970. Patterns of distibution of insects near a windbreak of tall trees. Ann. Appl. Biol. 65:213-220.

Lewis, T. 1973. **Thrips: Their Biology, Ecology and Economic Importance.** Academic Press, London and New York, 349 pp.

Lynch, R.E., J.W. Garner and L.W. Morgan. 1984. Influence of systemic insecticides on thrips damage and yield in florunner peanuts in Georgia. J. Agric. Ent. 1(1): 33-42.

Lysaght, A.M. 1937. An ecological study of a thrips (*Aptinothrips rufus*) and its nematode parasite (*Anguillulina aptini*). J. Animal Ecol. 6:169-192.

Lyubenov, Y.A. 1961. A contribution to the bionomics of the wheat thrips (*Haplothrips triciti* Kurd.) in Bulgaria and possibilities of reducing the injury done by it. Rev. Appl. Ent. (A) 50:348.

MacLeod, D.M., D. Tyrrell and K.P. Carl. 1976. *Entomophthora parvispora* sp, *nov*., a pathogen of *Thrips tabaci*. Entomophaga 21:307-312.

MacGill, E.I. 1939. A gasamid mite (*Typhlodromus thripsi* n. sp.) a predator of *Thrips tabaci* Lind. Ann. Appl. Biol. 26:309-317.

Madsen, H.F. and I.D. Jack. 1966. The relation of thrips to pansy spot on apples. Can. Ent. 98:903-908.

Madsen, H.F., H.F. Peters and J.M. Vakenti. 1975. Pest management: experience in six British Columbian apple orchards. Can. Ent. 107(8):873-878.

Madsen, H.F. and B.E. Carty. 1977. Pest management : four years experience in a commerical apple orchard. J. Ent. Soc. B.C. 74:3-6.

Madsen, H.F. and P.J. Procter. 1982. **Insects and Mites of Tree Fruits in British Columbia.** Min. of Agriculture and Food ISBN-0-7719-9028-6, Victoria, B.C.

McEwen, F.L. and G.R, Stephenson. 1979. The Use and Significance of Pesiticides in the Environment. John Wiley and Son, Publishers, New York. 538 pp.

McGregor, S.E. 1976. Insect pollination of cultivated crops. pp. 81-88. *in* Agriculture Handbook No. 496 U.S.D.A.

McMurtry, J.A. 1961. Current research on biological control of avocado insect and mite pests. Yearbook of Calif. Avocado Sci. 45:104-106.

Miller, A.V. and S.M. Craig. 1980. **Handbook for Pesticide Applicators and Pesticide Dispensers.** Pesticide Control Branch, British Columbian Ministry of Environment, Victoria, B.C. 233 pp.

Moffitt, H.R. 1964. A colour preferrence of the western flower thrips, *Frankliniella occidentalis* (on pears). J. Econ. Ent. 57(4):604-605.

Morgan, A.C. and S.E. Crumb. 1928. Notes on the chemotactic responses of certain insects. J. Econ. Ent. 21:913-920.

Morgan, C.V.G. and H.F. Madsen. 1976. **History of Fruit Growing and Handling in USA and Canada 1860 - 1972.** W.H. Upshall (ed.) Regatta City Press, Kelowna, B.C. p 256-275.

Morison, G.D. 1957. A review of British glasshouse Thysanoptera. Trans. Royal Ent. Soc. London 109:467-534.

Morse, J.G. and O.L. Brawner. 1986. Toxicity of pesiticides of *Scirtothrips citri* (Thysanoptera : Thripidae) and implications to resistance management. J. Econ. Ent. 79:565-570.

Muesbeck, C.F., K.V. Krombein and H.K. Townes. 1951. Hymenoptera of America North to Mexico, synoptic catalogue. Agric. Monogr. 2 1420 pp.

Mumford, E.P. and D.H. Hey. 1930. The water balance of plants as a factor in their resistance to insect pests. Nature, London 125:411-412.

Newcomer, E.J. 1921. A thrips injury to apples. Better Fruit 16:10.

Nickle, W.R. and G.W. Wood. 1964. *Howardula aptini* (Sharga 1932) parasitic in blueberry thrips in New Brunswick. Can. J. Zool. 42:843-846.

Norris, R.F. 1986. Weeds and integrated pest management systems. HortScience 21:402-410.

Ota, A.K. 1968. Comparison of three methods of extracting the flower thrips from rose flowers. J. Econ. Ent. 61:1754-1755.

Ota, A.K. and F.E. Smith 1968. Aluminum foil - thrips repellent. Am. Rose Ann. 53:135-139.

Penman, D.R., G.O. Osborne, S.P. Worner, R.B. Chapman and G.F. McLaren. 1982. Ethyl nicotinate, a chemical attractant for *Thrips obscuratus* (Thysanoptera : Thripidae) in stonefruit in New Zealand. J. Chem. Ecol. 8:1299-1304.

Pergande, T. 1895. Observations on certain Thysanoptera. Insect Life 7:390-395.

Pickford, R.J.J. 1984. Evaluation of soil treatment for control of *Thrips tabaci* on cucumber. *in* Tests of Agrochemicals and Cultivars. Ann. Appl. Biol. 5:18-19.

Pradesh, H. 1963. Occurrence of the thrips damaging apple blossoms in Himachal Pradesh. Indian J. Ent. 25:85-86.

Prokopy, R.J. and G.L. Hubbell. 1981. Susceptibility of apple to injury by tarnished plant bug adults. Environ. Ent. 10:977-979.

Ramakers, P.M.J. and M.J. VanLieburg. 1982. Start of commerical production and introduction of *Amblyseius mckenzei* Sch. and Pr. (Acarina : Phytoseiidae) for the control of *Thrips tabaci* Lind. (Thysanoptera : Thripidae) in glasshouses. Med. Fac. Landbouww. Rijksuniv. Gent. 47: 541-545.

Sakimura, K. 1937. On the bionomics of *Thripoctenus buri* Vuillet, a parasite of *Thrips tabaci* Lind, in Japan. Kontyû 11:370-390.

Samson, R.A., P.M.J. Ramakers, and T. Oswald. 1979. *Entomophthora thripidum*, a new fungal pathogen of *Thrips tabaci.* Can. J. Bot. 57:1317-1323.

Sharga, U.S. 1932. A new nematode, *Tylenchus aptini* n. sp., parasite of Thysanoptera (Insecta : *Aptinothrips rufus* Gmelin). Parasitology 24:268-279.

Sharma, P.L. and O.P. Bhalla. 1963. Occurrence of the thrips damaging apple blossoms in Himachal Pradesh. Indian J. Ent. 25:85-86.

Shorey, H.H. and I.M. Hall. 1963. Toxicity of chemical and microbial insecticides to pest and beneficial insects on poled tomatoes. J. Econ. Ent. 56:813-817.

Skroch, W.A. and J.M. Shribbs. 1986. Orchard floor management : an overview. HortScience 21(3):390-394.

Steiner, M.Y. and D.P. Elliott. 1983. Biological Pest Management for Interior Plantscapes. Alberta Agriculture, Alberta Envir. Centre, Vegeville, AB. 30 pp.

Stott, K.G. 1976. The effects of competition from ground covers on apple vigor and yield. Proc. Assn. Appl. Biol. 3:327-330.

Swift, J.E. and H.F. Madsen. 1956. Thrips damage to apple. J. Econ. Ent. 49:398-399.

Tanigoshi, L.K., J. Fargerlund, J.Y. Nishio-Wong, and H.J. Griffiths. 1985. Biological control of citrus thrips, *Scirtothrips citri* (Thysanoptera:Thripidae) in Southern California citrus groves. Envir. Ent. 14(6):733-741.

Taylor, E.A. and F.F. Smith. 1955. Three methods for extracting thrips and other insects from rose flowers. J. Econ. Ent. 48:767-768.

Taylor, L.R. 1962. The efficiency of cylindrical sticky traps and suspended nets. Ann. Appl. Biol. 50:681-685.

Thompson, W.R. 1950. A **Catalogue of the Parasites and Predators of Insect Pests. Section 1. Pt. 2. Parsites of the Neuroptera, Odonata, Orthoptera, Pscoptera, Siphonaptera and Thysanoptera.** Commonweath Agric. Bur., Ottawa 35 pp.

Thistlewood, H.M.A. 1986. **Bionomics and Monitoring of** ***Campylomma verbasci*** **(Meyer) on Apple in the Okanagan Valley, B.C.** Phd. Thesis, Simon Fraser University, Burnaby B.C.

Tippins, H.H., and L.L. Hyche. 1955. Control of flower thrips on blackberries. J. Econ. Ent. 48:768-769.

Trichilo, P.J. and T.F. Leigh. 1988. Influence of resource quality on reproductive fitness of flower thrips (Thysanoptera : Thripidae). Ann. Ent. Soc. Am. 8:64–70.

Venables, E.P. 1925. Pansy spot on apple (a peculiar form of thrips injury). Proc. Ent. Soc. B.C. 22:9–12.

Verma, K.L. 1979. Apple blossom thrips (*Taeniothrips* sp.) and their control. Pesticides 13(1):32–33.

Vertinghoff–Riesch, von A.F. 1958. Untersuchungen über vertreitungjund schadwirkling des lärchenblasenfussen (*Taeniothrips laricivorus* Krat.) in den randzonen seines verbreitungsgebietes in Norddeutschland, der Schweiz und Frankreich. Zeit. Ang. Ent. 41:449–474.

Walsh, J. 1976. Cosmetic standards : are pesticides overused for appearances sake?. Science 193(4255):744–747.

Weiss, M.J. and R.J. Beshear. 1987. Seasonal distribution of the flower thrips (*Frankliniella tritici* (Fitch)) and onion thrips (*Thrips tabaci* Lindeman)(Thysanoptera : Thripidae) on safflower in eastern Montana. Can. Ent. 119:399–401.

Wilson, T.H. and T.A. Cooley. 1972. Planidium and an entomophilic nematode associated with the western flower thrips. Ann. Ent. Soc. Am. 65(2):414–418.

Zar, J.H. 1974. **Biostatisical Analysis.** Prentice–Hall, Inc. Englewood, New Jersey. 620 pp.

APPENDIX A

Host Plants of the Western Flower Thrips

Aceraceae : *Acer* sp., (maple)
Apocynaceae : *Trachelopermum jasminoides* L., (confederate jasmine)
Boraginaceae : *Amsinckia intermedia* F. and M., (fiddleneck)
Capparidaceae : *Isomeris arbores* Nutt., (burro fat)
Caprifoliaceae : *Sambucus glauca* Nutt., (blue eldberry); *Viburnum* sp.
Caryophllaceae : *Dianthus caryophyllus* L., (carnation); *Gypsophilia paniculata* L., (baby's breath)
Chenopodiaceae : *Atriplex rosea* L., (salt bush)
Cistaceae : *Cistus* sp. (rock rose)
Compositae : *Achillea millefium* L., (yarrow); *Anthemis cotula* L., (mayweed); *Artemisia californica* Less., (sagebrush); *A. vulgaris* L.; *Baccharis pilularis* D.C., (coyote brush); *Baerta* sp.m (gold fields); *Calendula* sp., (marigold); *Centaurea solsitialis* L., (yellow star thistle); *Chrysanthemum leucanthemeum* L., (ox-eye daisy); *Chrysothamnus* sp., (rabbit brush); *Cichorium intybus* L., (chicory); *Cirsium* sp., (thistle); *Cynara scolymus* L., (artichoke); *Erigeron foliosus* Nutt., (fleabane); *E. glaucus* Ker., (seaside daisy); *Eriophyllum staechadifolium* Lag., (lizard tail); *Gnaphalium decurrens* Ives., var. *californica* Gray, (California everlasting); *G. ramosissimum* Nutt., (pink everlasting); *Grindelia camposum* Greene; *G. robusta* Nutt., (gum plant); *Helianthus annus* L., (common sunflower); *Hemizonia corymbosa* (D.C.) T. and G., (coast tarweed); *Hypochoeris radicata* L., (hairy cat's-ear); *Lactuca sativa* L., (lettuce); *Monolopia major* D.C.; *Picris echioides* L., (bristly ox-tongue); *Senecio vulgaris* L.; *Solidago californica* Nutt., (commom golden rod); *Solidago canadensis* L., (golden rod); *Taraxacum officinale* (dandelion)
Convolvulaceae : *Convolvulus luteolus* Gray (morning glory)
Cornaceae : *Cornus stolonifera* Michx., (red osier dogwood)
Crassulaceae : *Sedum* sp., (stone crop)
Cruciferae : *Brassica capestris* L., (mustard); *Brassica incana* Penore; *Cakile edentula* Hook var. *californica* Per., (sea rocket); *Capsella bursa-pastoris* (L.) Moench., (shepherd's purse); *Iberis amara* L., (candy tuft); *Radicula nasturtium-aquaticum* (L.) Brett. and Rendl., (water cress); *Raphanus sativua* L., (wild radish)
Cururbitaceae : *Citrullus vulgaris* Schrad., (watermelon); *Cucumis melo* Naud. var. *cantanlupensis*, (cantaloupe); *Cucumis sativus* L., (cucumber); *Cucurbita pepo* L., (squash)
Ericaceae : *Arbutus menziesii* Pursh., (madrono); *Arctostaphyllus* sp., (manzanita); *Rhododendron* sp., (azalea)
Euphoribaceae : *Eremocarpus setigerus* Benth., (turkey mullein)
Geraniaceae : *Geranium* sp.
Graminae : *Hordeum vulgare* L., (barley); *Koeleria cristata* (L.) Pers.; *Polypogon monapeliensis* (L.), (beard grass); *Triticum aestivum* L., (wheat)
Hypericaceae : *Hypericum perforatum* L., (St. John's wort)
Iridaceae : *Gladiolus* sp.,
Juglandaceae : *Carya illinoensis* Koch, (pecan); *Juglans nigra* L., (black walnut)
Juncaceae : *Juncus xiphioides* F.Mey., (rush)
Labiatae: *Marrubium vulgare* L., (horehound); *Mentha arvensis* L., (tule mint); *Physostegia virginiana* Benth., (false dragonhead); *Stachys bullata* Benth., (hedge nettle); *Trichostema lanceolatum* Benth., (vinegar weed)

Lauraceae : *Persea* sp., (avocado); *Umbellularia californica* Nutt., (California laurel)
Leguminosae : *Astragalus douglasii* Gray, (rattleweed); *Cercis occidentalis* Torr., (red bud); *Cytisus monspessulanus* L., (French broom); *Lathyrus odoratus* L., (sea pea); *Lupinua arboreus* Sims., (lupin); *L. bicolor* Lundl.; *L. succulentis* Dougl.; *Medicago hispida* Gaertn., (bur clover): *M. sativa* L., (alfalfa); *Metilotus alba* Desr., (sweet clover); *Parkinsonia microphylla* Torr., (palo verde); *Phaseolus* sp., (bean); *Pisum sativum* L., (pea); *Trifolium hybridum* L., (alsike clover); *T. pratense* L., (red clover); *T. repens* L., (white clover); *T. tridentatum* Lindl. (tomeat clover); *Vicia* sp., (vetch); *Wisteria* sp.,
Lilaceae : *Allium cepa* L., (onion); *Brodiaea capitata* Benth., (blue dicks)
Linaceae : *Linum uditatissimum* L., (flax)
Malvaceae : *Althaea rosea* Cac., (hollyhock); *Gossypium hirsutum* L., (upland cotton); *Sidalcea glaucescens* Greene; *Sphaeralcea umbellata* Don.
Nyctaginaceae : *Abronia latifolia* Esch., (yellow sand-verbena); *Bougainvillea spectabilis* Willd.,
Oleaceae : *Olea europaea* L., (olive); *Syringia* sp., (lilac)
Onagraceae : *Godetia amoena* (Lehm) (lilja summer's darling); *Zauschneria californicus* Presl., (Mexican balsamea)
Papaveraceae : *Eschscholtzia californica* Cham., (california poppy); *Platystemon californicus* Benth., (cream cups)
Pinaceae : *Abies magnifica* Murr., (red fir); *Pseudotsuga taxifolia* (Lamb.) Brett., (Douglas fir)
Polygonaceae : *Eriogonum gracile* Benth.; *Polygonum aviculare* L. (wire grass); *Rumex cripus* L., (curly dock); *Polygonum persicaria* L.
Plumbaginaceae : *Plumbago capensis* Thunb. (leadwort)
Ranunculaceae : *Clematis montana* Buch. Ham.; *Ranunculus californicus* Benth., (California buttercup)
Rhamnaceae : *Ceanothus cordulatus* Kell., (snow-brush); *C. integerrimus* H. and A., (deer brush); *C. velutinus* Dougl. (tobacco brush)
Rosaceae : *Amelanchier cusickii* Fern, (saskatoon); *Fragaria*, (strawberry); *Malus* sp. (apple); *Photinia arbutifolia* Lindl., (Christmas berry); *Potentilla* sp., (five finger); *Prunus armeniaca* L., (apricot); *Prunus persica* Batsch, (peach); *Prunus domestica* L., (prune); *Purshia tridentata* D.C., (bitter brush); *Pyrus communis* L., (pear); *Rosa californica* C. and S., (California wild rose); *Rosa* sp., (rose); *Rubus* sp., (dewberry); *Rubus* sp., (raspberry)
Rutaceae : *Citrus limon* Burm., (lemon); *Citrus sinesis* Osbeck, (orange)
Salicaceae : *Salix* sp., (willow)
Sapindaceae : *Aesculus californica* (Spach) Nutt., (buckeye)
Scrophulariaceae : *Diplacus aurantiacus* Jepson, (bush monkey-flower); *Mimulus guttatus* D.C.; *Orthocarpus lacerus* Benth.
Solanaceae : *Capsicum annuum* L., (pepper); *Capsicum frutescens* L.; *Nicotianaglauca* Graham, (tree tobacco); *Lycopersicum esculentum* Mill., (tomato); *Solanum melongena* L., (egg plant); *Solanum tuberosum* L., (potato)
Tropaeolaceae : *Tropaeolum majus* L., (nasturtium)
Verbenaceae : *Lantana camara* L.
Violaceae : *Villa* sp., (violet)
Vitaceae :*Vitus vinifera* L., (grape)
Adapted from: Broadbent and Allen 1987; Weiss and Beshear 1987; Bryan and Smith 1956; Bailey 1938.

APPENDIX B

Pesticides Referenced

Common Name	Trade Name	Chemical Name
acephate	Orthene®	
aldicarb	Temik®	2-methyl-2-(methylthio)propionaldehyde-X-(methylcarbamoyl)oxiome
aldrin	Aldrin®; Aldrite®; Aldrex®; Soildrin®	1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-*exo*-1,4-*endo*-5,8-dimethanonaphtalene
arsenicals		
BHC	Benzahex®	1,2,3,4,5,6-hexachlorocyclohexane
Bacillus thuringiensis	Dipel®; Thuricide®; Biotrol®	
carbaryl	Sevin®	1-naphthyl-*N*-methylcarbamate
carbopenothion	Garrathion®; Trithion®	
Terbufos	Counter® 15 G	*S*-{(tert-butylthio)methyl} *O,O*-diethyl phosphorodithioate
cyromazine (igr)		
DDT	many	1,1,1-trichloro-2,2-bis(parachlorophenyl) ethane
deltamethrin		
derris		
diazinon	Basudin®; Spectracide®	*O,O*-diethyl *O*-2-isopropyl-4-methyl-6-pyrimidyl phosphorothioate
dicrotophos	Bidrin®	3-hydroxy-*N,N*-dimethyl-*cis*-crotonamide dimethyl phosphate
dieldrin	Distan®; Octalox®	1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-*exo*-1,4-*endo*-5,8-dimethanonaphthalene
dimethoate	Cygon®; DeFend®; Roger®; Sys-Tem®	*O,O*-dimethyl *S*-(*N*-methyl carbomyl methyl) phosphorodithioate
dinoseb	DNPB®; Dow General®; Sinox General®	2,4,-dintro-*sec*-butyl phenol
DNOC	Elgetol®	sodium dinitro-o-cresol
ethion		0,0,0,0-tetra-ethyl *S,S*-methylene *bis* phosphorodithioate
fenitrothrin	Baytex®; Novathion®; Sumithion®	*O,O*-dimethyl 0-3-methyl-4-nitrophenol phosphorothionate
fenthion	Baytex®; Entex®; Queletox®; Tiguvon®	*O,O*-dimethyl 0-{-4-(methylthio) m toyl} phosphorthioate
fenvalerate	Belmark®; Sumicidan®; Pydrin®; S5602®; SD 43775®	cyano(3-phenoxyphenyl)mothyl 4-chloro-α-(1-methylethyl) benzeneacetate
fluosilicates	Prodan®	
Kerosene soap		

malathion	Cythion®	*O,O*–dimethyl *S*(1,2–dicarboxyethyl) phosphorodioate
methyl carbo–		
phenothion		
mehtyl demeton		
monocrotophos	Azodrin®	dimethyl cis–1–methyl–2–methyl–carbamoylvinyl phosphate
MSMA		monosodium methanearsonate
nicotine		(–)1–methyl–2(3'–pyridyl)pyrrolidine
parathion	Aqua®; Paraflow®	0,0–diethyl–0–nitrophenyl phosphorothionate
permethrin	Ambush®; Decis®; Ectiban®;NRDC 161®; Pounce®; RU 22974®	(3–phenoxyphenyl) methyl 3–(2,2–dichloroethenyl)–2,2–dimethyl–cyclopropanecarboxylate
phosalone		S–{(6–chloro–2–*oxo*–3 benzoxazolinyl methyl} *O,O*–diethyl phosphorodithioate
pyrethrum		
rotenone		(–)2–(3'–pyridyl)piperidine
sulphur washes,dusts		
see aldicarb	TEMIK 15 G	
toxaphene	Alltox®; Phenatox®	2,2,5–*endo*–6–*exo*–8,9,10–heptachlorobornene
UC84572 (IGR)		

——— Adapted from : Adams 1987; Buchel and Holmwood 1983; Bohmont 1983; Hassall 1982; Miller and Craig 1980; McEwen and Stephenson 1979; Cremlyn 1978.

APPENDIX C

Questionaire Sent to Orchardists

Name________________________________
Address________________________________
Telephone Number________________________________

1. How many acres of orchard do you operate?____________
2. What are the major varieties of apples that you grow? (Please check)
Macintosh ____________
Red Delicious ____________
Golden Delicious____________
Spartan ____________
Other (please specify)________________________________
3. Are the majority of your apple trees :
Dwarfs (or semi-dwarfs) ____________
Standards ____________
4. Do you mow the grass in your orchards before bloom starts?
Always ____________
Never ____________
If time allows ____________
5. Do you usually hire honey bee hives?
Yes ____________
No ____________
6. Do the surrounding orchardists hire honey bee hives?
Yes ____________
No ____________
Some do ____________
7. Are there other commerical orchards within 1 mile of your orchard?
Yes ____________
No ____________
8. Is there a large area (1/2 acre or more) of uncultivated land adjoining your orchard?
Yes ____________
No ____________
9. What do you consider to be your two **worst** insect problems in your orchard?
1________________________
2________________________
10. Would you be willing to assist me in my research by allowing me to work in your orchard?
Yes ____________
No ____________
Thank you.