AN ABSTRACT OF THE THESIS OF

Mohammad Saeed for the degree of Master of Science in Entomology presented on July 25, 1989.

Title: Toxicity of Some Commonly Used Pesticides to Trioxys pallidus and Its Establishment in Filbert Orchards of Willamette Valley.

Redacted for Privacy

Abstract approved: --

Dr. M. T. AliNiazee

A parasitic wasp, *Trioxys pallidus* Haliday (Hymenoptera: Aphidiidae) was imported from Europe and initially released against the filbert aphid *Myzocallis coryli* (Goetze) in hazelnut (filbert) orchards of the Willamette Valley, Oregon beginning in 1984. In the present study, I investigated the establishment rates of this parasitoid. A total of 13 orchards in 1987 and 30 orchards in 1988 were sampled twice per year. Five to ten trees were selected at random in each orchard and these trees were sampled by collecting and examining ten twigs per tree and counting the number of aphids and aphid mummies on four leaves per twig. The rate of parasitization was calculated by Total No. of mummies / Total No. of aphids + mummies X 100. Data show that the parasitoid has established in many commercial orchards and out of the total of 30 orchards studied eleven had

breeding population of Trioxys pallidus and that is rapidly moving to adjoining orchards. The parasitoid appears to have survived the standard insecticide applications in commercial orchards.

The level of resistance of a field collected population of Trioxys pallidus to the most commonly used pesticides in the filbert system including Metasystox-R, Pydrin, Zolone, Diazinon, and Lorsban was determined. Adult parasitoid populations continuously exposed to Pydrin (2 sprays per year) and carbaryl (1 spray per year) since 1985, were collected near Corvallis, Benton County, Oregon and their response to various insecticides was assessed. Similar data were collected from a laboratory reared susceptible population which was never exposed to insecticides.

Comparasion of LC50 and LC95 values showed no significant differences in the susceptibility of these two populations to test insecticides, although build up of some tolerance against Pydrin was evident. The field population required 1.9 times higher rate than the laboratory population for 50% mortality. Metasystox-R was highly toxic to both populations with LC50 values of 1.06 ppm and Lorsban was the least toxic with LC50 of 28.3 ppm. An insecticide toxicity rating was determined. The test chemicals were rated in a decreasing order of toxicity as Metasystox-R, Pydrin, Zolone, Diazinon and Lorsban.

TOXICITY OF SOME COMMONLY USED PESTICIDES TO *TRIOXYS PALLIDUS* AND ITS ESTABLISHMENT IN FILBERT ORCHARDS OF WILLAMETTE VALLEY

by

Mohammad Saeed

A THESIS

submitted to

Oregon State University

in partial fulfillment of

the requirements for the

degree of

Master of Science

Completed July 25, 1989

Commencement June 1990

APPROVED:

Redacted for Privacy

Professor of Entomology in charge of major

Redacted for Privacy

Head of Department of Entomology

Redacted for Privacy

Dean of Graduate School

Date thesis is presented July 25,1989

ACKNOWLEDGEMENTS

I wish to express my sincere and special thanks to my major professor, Dr. M. T. AliNiazee, for his invaluable advice, continued encouragement and financial support during the course of studies and research. The completion of manuscript was only possible due to his discrete criticism, kind supervision and sympathetic out look.

Heartfelt appreciation is also extended to my committee members, Dr. Jeffrey C. Miller, who materially helped me by allowing the use of the greenhouse facilities and getting me interested in the basic and applied aspects of biological control, Professor Wilbert L. Andersen, for his generous help, invaluable suggestions and always availability, and Dr. Arthur J. Boucot who kindly agreed to be on my committee and extended full cooperation.

Thanks are also due to all faculty, staff and students of the Entomology department for their friendship and help with smiling faces.

Last but not the least, I would like to express my deep appreciation to my wife, Shahida, for her unending support, many sacrifices and patience along with childrens love while waiting to see their grandparents after a long time..

TABLE OF CONTENTS

PAGE

I. INTRODUCTION..1

II. LITERATURE REVIEW..................................6

III. ASSESSMENT OF *TRIOXYS PALLIDUS* ESTABLISHMENT IN FILBERT ORCHARDS OF OREGON

ABSTRACT...13

INTRODUCTION.....................................14

METHODS AND MATERIALS 15

RESULTS..17

DISCUSSION.......................................40

REFERENCES CITED.................................47

IV. RELATIVE TOXICITY OF SOME COMMONLY USED PESTICIDES TO *TRIOXYS PALLIDUS* IN FILBERT ORCHARDS OF OREGON

ABSTRACT...49

INTRODUCTION.....................................50

METHODS AND MATERIALS 52

Orchards.....................................52

Insecticides.................................53

Bioassays....................................55

RESULTS..57

DISCUSSION.......................................72

REFERENCES CITED.................................75

V. SUMMARY AND CONCLUSION.............................77

VI. BIBLIOGRAPHY......................................80

VII. APPENDIX...87

LIST OF FIGURES

FIGURE PAGE

1. Map of Willamette Valley, Oregon, showing location of orchards where Trioxys pallidus was released and has established...............21

2. Map showing movement of Trioxy pallidus in Twedt Orchard 1984-1988......................28

3. Aphid density at Twedt Orchard (south side) before and after releases of Trioxys pallidus. (Counts taken during peak seasnal activity period).....30

4. Rate of parasitization of M. coryli by T. pallidus in Twedt Orchard during spring and fall of 1987 & 1988.....................................31

5. Rate of parasitization of M. coryli by T. pallidus in Calef Orchard during spring and fall of 1987 & 1988.....................................32

6. Rate of parasitization of M. coryli by T. pallidus in Simonson Orchard during spring and fall of 1987 & 1988.....................................33

7. Rate of parasitization of M. coryli by T. pallidus in Gray Orchard during spring and fall of 1987 & 1988.....................................34

8. Rate of parasitization of M. coryli by T. pallidus in Buchanan Orchard during spring and fall of 1987 & 1988.....................................35

9. Rate of parasitization of M. coryli by T. pallidus in Knittel Orchard during spring and fall of 1987 & 1988.....................................36

10. Rate of parasitization of M. coryli by T. pallidus in Lemert Orchard during spring and fall of 1987 & 1988.....................................37

11. Rate of parasitization of M. coryli by T. pallidus in Duncan Orchard during spring and fall of 1987 & 1988.....................................38

12. Rate of parasitization of M. coryli by T. pallidus in Newton Orchard during spring and fall of 1987 & 1988.....................................39

13. LDP lines of two populations of *T. pallidus* exposed to Metasystox-R........................59

14. LDP lines of two populations of *T. pallidus* exposed to Pydrin..............................60

15. LDP lines of two populations of *T. pallidus* exposed to Zolone..............................61

16. LDP lines of two populations of *T. pallidus* exposed to Diazinon............................62

17. LDP lines of two populations of *T. pallidus* exposed to Lorsban.............................63

18. LDP lines of field collected population of *T. pallidus* exposed to five pesticides 64

19. LDP lines of laboratory reared population of *T. pallidus* exposed to five pesticides.........65

LIST OF TABLES

Table Page

I-1. Site and field releases of *Trioxys pallidus*....18

I-2. Incidence of *Trioxys pallidus* in orchards sampled during 1987....................................22

I-3. Incidence of *Trioxys pallidus* in orchards sampled during 1988....................................24

I-4. Pesticide use pattern where *Trioxys pallidus* was released....................................45

II-1. Insecticides used for experiments..............54

II-2. Comparative susceptibility to insecticides of two populations of *Trioxys pallidus* (field and lab.) at LC50 values................58

II-3. Comparative susceptibility to insecticides of two populations of *Trioxys pallidus* (field and lab.) at LC95 values................67

II-4. Relative toxicity of five different insecticides to two populations of *Trioxys pallidus* 69

II-5. Mortality of two populations of *Trioxys pallidus* at sub-lethal rates of five insecticides.......70

A-1. List of *Trioxys pallidus* releases..............87

TOXICITY OF SOME COMMONLY USED PESTICIDES TO *TRIOXYS PALLIDUS* AND ITS ESTABLISHMENT IN FILBERT ORCHARDS OF WILLAMETTE VALLEY

I. INTRODUCTION

The filbert (hazelnut), *Corylus avellana* L. was brought to this country during colonial days, but attained little commercial importance until its introduction to the Northwest around the turn of the century (Richard 1968). The mild climate and the absence of the eastern filbert blight on the native hazelnut of this area, *Corylus cornuta* Marsh, *Corylus americana* Marsh, (also called *Corylus californica*), make the Willamette Valley of Oregon and the corresponding areas in Washington, the most suitable for filbert growing in the United States. The Willamette Valley produces about 97% of the total crop grown in United States. Filbert yield under most favorable conditions and at the full maturity of the trees, may run over 3,000 lb. per acre.

Annual production of filberts in the United States averages over 29 million pounds, but does not fulfill the consumer demand of the country. As more and more filbert acreage is coming into bearing annually, 25,490 acres in 1984-1985 as compared to 19,420 acres in 1976-1977 (Filbert Tree Report 1985), high emphasis is being placed on increasing yields. The filbert industry in Oregon is growing rapidly due to an increased demand for nuts, higher profitability and the recent introduction of improved varieties.

The pest insects are some of the most serious problems for increased filbert production in the United States. Like other crops, the filbert ecosystem has its own pest complex (AliNiazee 1980, 1983a, 1985). This includes four major pests, which are: the filbertworm, Melissopus latiferreanus (Wals.), the filbert aphid, Myzocallis coryli (Goetze), the filbert leafroller, Archips rosanus (L.) and the obliquebanded leafroller, Choristoneura rosaceana (Harris). Secondary pests include: the filbert bud mites, Phytoptus avellanae (Nalepa) and Cecidophyopsis vermiformis (Nalepa), the omnivorous leaftier, Cnephasia longana (Haworth), filbert nut weevils, Curculio uniformis Le Conte and Curculio obtusus Le Conte, scale insects, Lecanium corni (Bouche) and Lecanium excrescens (Ferris), the syneta beetle, Syneta albida (Lec.), eyespotted bud moth, Spilonota ocellana (Denis and Schiffer-Muller), tree crickets, Oecanthus niveus (DeGeer) and Oecanthus nigricornis (F. Walker), and the apple mealybug, Phenacoccus aceris (Signoret).

The filbert aphid is one of the most commonly mentioned insect problems by growers in the Willamette Valley and is a serious pest in many filbert orchards.

Under optimum conditions, aphid population levels of 200-300 per leaf are frequent (Messing, 1986). At these densities, a large amount of honeydew is deposited on leaves, upon which a sooty mold fungus develops. This causes sticky and stained nuts with fouling of orchard equipment. Although no accurate estimates are available, it is generally agreed by filbert horticulturists, entomologists, and growers that high aphid populations reduce plant growth and adversely affect yields.

At present, the Insect Pest Management (IPM) program on filberts recommends an action threshold of 20-40 aphids per leaf (Calkin et al. 1985) for applying control treatments. Most of the filbert growers of Oregon use pesticides to control filbert aphid. These treatments cost $15-25 per application per acre and contribute to about 5% of the total crop production costs (Messing 1986). AliNiazee (1983a) has shown that these costs are negative expenditures as they contribute to increased density of other pests. Moreover, filbert aphid has developed resistance to carbaryl and other insecticides most commonly used in commercial hazelnut orchards (AliNiazee 1983b, Katunda and AliNiazee 1989). Biological control, therefore, seems to be an ideal option.

Predators, particularly, coccinellids, chrysopids, syrphids and mirids, which are commonly found in the orchards, are capable of providing good natural control, although the efficiency is limited by their tendency to colonize orchards late in the season and their susceptibility to insecticides applied for other pests (Messing and AliNiazee 1985). For this reason, biological control using a host specific parasitoid may provide an effective alternative. With this in mind, an extensive survey for natural enemies of filbert aphid was conducted in Europe (Messing and AliNiazee 1988), and a population of Trioxys pallidus Haliday from France was introduced to the Willamette Valley during the 1984 season. This population was later mass produced in greenhouses and a number of releases were made in filbert orchards throughout the Willamette Valley.

During the 1987 and 1988 years, detailed field surveys were conducted to asses the establishment and spread of T. pallidus. It was evident in these surveys that the parasitoid was adversely affected by the pesticide used, consequently, its establishment and survival was disrupted. The pesticide exposure history of the imported population was unknown, however, its susceptibility to commonly used organophosphate (OP) compounds suggests that it was highly susceptible to insecticides. Also, relatively little data was available on toxicity of individual compounds to T. pallidus. Since the potential success of this parasitoid in Oregon was dependent on its ability to colonize and provide effective suppression of aphid populations and to survive the sprays of commonly used pesticides in the filbert orchards, information on establishment, efficacy and pesticide susceptibility of T. pallidus was essential. In addition, documentation of any development of resistance to commonly used pesticides in the field needed to be checked.

The objectives of this study were therefore,

a) to assess the establishment of T. pallidus in selected filbert orchards of Oregon, and

b) to determine the toxicity of most commonly used pesticides to T. pallidus and to detect the development of resistance in field populations of this parasitoid.

The development of such information will certainly be useful in implementation of integrated pest control programs involving incorporation of chemical and biological controls (Ripper 1956, Smith and Hagen 1959, Stern et al 1960, and Pimentel 1961).

II. LITERATURE REVIEW

The filbert (hazelnut) family Betulaceae (birch family) is known to occur in pre-boreal period about 8,000 to 7,500 B.C. (Kasapligil 1963). Its habitat ranges from high Himalayas to the northern reaches of Canada. Its commercial production is limited to Turkey, Italy, Spain, France and the United States. In the U.S.A., 95% of the total production is grown in the Willamette Valley of Oregon (Baron and Stebbin 1981). The cultivated filbert, which is European in origin, was first introduced to the west coast by Felix Gillet, a French barber who started a nursery in the gold-mining town of Nevada City, California in 1871 (Lagerstedt 1975). The culture expanded slowly as more and more growers in the mid Willamette Valley realized the climatic suitability of this area for growing filberts. Currently, over 29,000 acres of filberts are grown in the Valley and the acreage is expected to top nearly 35,000 acres during the next 10 years.

A large number of insects are associated with the hazelnut. Godwin (1956) reported a total of 136 insect species from this plant. However, relatively few are pests (AliNiazee 1980). The filbert aphid was first described in Europe by Goetze in 1778, and it was probably introduced into the U.S.A. along with filbert rootstock in 1880 (Richard 1965), but was recorded for the first time as a filbert pest in this region in the 1920's (AliNiazee 1983b, 1985). At present, it is a major pest of filberts in the Willamette Valley and contributes to substantial losses due to reduced quality of nuts (Painter and Jons 1960). El-Haidari (1959) conducted a detailed biological study of this pest, and reported 10-11 generations per year in Oregon. He reported that the overwintering eggs hatch in March, and large aphid populations build up during May. Peak populations occur from late May to early July and are followed by sharp declines in late July and August. The natural enemies of the filbert aphid were studied by Messing and AliNiazee (1985), who reported that generalist predators are partly responsible for the decline of aphid populations late in the season. The impact of predators on aphids in general is reviewed by Hagen and van den Bosch (1968) and by Hodek (1966). Biology of the aphid parasitoids in the family Aphidiidae is discussed by Stary (1970) and Mackauer and Stary (1967). The principles and techniques of classical biological control are reviewed by many authors including DeBach (1964), Huffaker (1969), Huffaker and Messenger (1976) and those involving aphids are summarized by Clausen (1978) and Hagen and van den Bosch (1968).

The Trioxys group is one of the prominent, effective and most prevailing candidates as a biological control agent of different aphids in the tribe Callaphidini throughout the world. In the United States four different projects were under taken during the last four decades that involved importation of some species of Trioxys. These include; a) spotted alfalfa aphid Therioaphis maculata (Buckton) parasitized by Trioxys complanatus (Quilis), b) walnut aphid, Chromaphis juglandicola (Kalt) by Trioxys pallidus Haliday, c) elm aphid, Tinocallis platani (Kalt) by Trioxys tenuicaudus (Stary), d) linden aphid, Eucallipterous tilia (L.) by Trioxys curvicaudus (Mackauer), and more recently, e) filbert aphid, Myzocallis coryli (Goetz) by Trioxys pallidus Haliday. All of these parasitoids have successfully gone through the initial stages of establishment and some are playing a major role in IPM programs for controlling these aphids. T. complanatus was rapidly established in California (van den Bosch et al. 1958 and Hagen et al. 1958) and then was distributed to other western states.

The bionomics of T. complanatus were investigated by a number of researchers (Schlinger and Hall 1959, 1961; Force and Messenger 1964, 1965, 1968; Flint 1980). Its climatic adaptation was studied by van den Bosch et al. 1959), and the probability of establishment by Beirne (1975). Similarly, T. pallidus Haliday, was imported from southern France and released in several counties of California against the walnut aphid. It established rapidly and overwintered successfully (Schlinger et al. 1960). It was very effective against the aphid (van den

Bosch et al. 1962), but unfortunately it could not survive under the high temperatures and low humidity of inland areas. Later, a different population of T. pallidus from Iran was imported and released in the interior valleys of California where it was rapidly established (van den Bosch et al. 1970). Due to continued success of T. pallidus in the suppression of walnut aphid population (as described by Sluss 1967, Frazer and van den Bosch 1973, Nowierski 1979), it is estimated that the parasitoid is benefiting the walnut industry in California by one-half to one million dollars annually (van den Bosch et al. 1979).

In the early 1970's a number of other Trioxys species were imported for controlling ornamental tree aphid, but only T. curvicaudus and T. tenuicaudus became established in the Berkeley area and contributed significantly to control of Eucallipterous tilia and Tinocallis platani respectively (Olkowski et al. 1976, 1982).

T. pallidus on walnut aphid was probably accidently introduced to the Willamette Valley and is quite prevalent in many valley locations. It does keep the population of the walnut aphid under control, but fails to move to filbert aphid (Messing and AliNiazee 1988). In an attempt to improve biological control of the filbert aphid, T. pallidus populations from Europe were introduced and established in the Willamette Valley

(Messing and AliNiazee 1988). In some orchards the parasitoid has been established in spite of the use of numerous pesticides including Sevin, Diazinon and Pydrin. In addition to these three insecticides a number of other compounds such as Parathion, Guathion, Malathion, Thiodon, Zolone, Systox, Metasystox-R, Ambush, and Pounce are registered for use on filbert (PNW insect control hand book 1988).

Beside direct mortality, the pesticides have a number of other harmful effects on beneficial insects. These may include starvation due to lack of prey, feeding on the insecticide-affected hosts, emigration or behavioral changes due to reduced availability of hosts after the reduction of pest population by the pesticide (Croft and Brown 1975, Huffaker 1971, Newsom 1974, Powell et al. 1985, van den Bosch et al. 1956). In general, adults of delicate internal parasitic hymenoptera are as susceptible to contact pesticides as are their respective host.

Toxicity to the parasitic species is a function of dosage and rate of toxic residue degradation, where low dosages suffice for destruction of the pests, a few of the most selective insecticides may at times permit the survival of some adult parasites directly contacted (Bartlett 1958). Calkin et al.(1985) and Messing (1982) found that Zolone was slightly less toxic to natural enemies of the filbert aphid than other insecticides. A similar selectivity was noticed by Shorey (1963) in Demeton, which was one of the most effective aphicides but, appeared to be selective, permitting the survival of a good population of the Diaeretiella rapae (M'Intosh) and Hippodamia spp. in alfalfa. Similar observations were recorded by Bartlett (1958) who considered Demeton as the most practical material for the integrated control of the spotted alafalfa aphid, Therioaphis maculata (Buckton). Purcell and Jeffrey (1985) found that benzoyl phenyl ureas and Bacillus thuringiensis were not toxic to T. pallidus, whereas, Zolone and Guthion were extremely toxic to parasitoid. Differential relative toxicity of some of the most widely used insecticides to certain important beneficial insects occuring on cotton was noticed by Newsom and Smith (1949), Campbell and Hutchins (1952).

Pesticide selectivity has been achieved due to resistance in natural enemies (Croft 1989) as well as avoidance mechanisms. In California T. pallidus has developed low level of resistance to some commonly used walnut insecticides (Hoy 1988). Schoones and Giliomee (1982) found a 5.7 and 65.6 fold difference in the level of resistance to methidathion in two field population of Aphytis africanus Quednau and two field populations of Comperiella bifasciata Howard, respectively. Strawn (1978) found significant interpopulation variation in the tolerances of Aphytis melinus adults to dimethoate, methidathion, and parathion. Hsieh (1984) reported ca. 2-fold difference between the tolerances exhibited by two field populations of Diaeretiella rapae to methomyl. This suggests development of different kinds of resistance under field condition ranging from undetectable to substantial.

The evolution of resistance in field populations of parasitoid may often go unnoticed (Croft and Brown, 1975). The differential exposures of parasitoids relative to their hosts due to morphological, behavioral, or ecological differences may lead to a greater effective toxicity (Georghiou 1972). However, the lack of genetic flexibility among the highly ecologically specialized parasitoids may restrict the evolution of resistance (Huffaker 1971, Georghiou 1972). Although the development of resistance in pest species is common (428 recorded cases as of 1984), it is generally rare in natural enemies. The most common beneficial group resistant to pesticide is the predatory mites of deciduous fruit trees (Ware 1980, Croft and Stickler 1983).

III. ASSESSMENT OF *TRIOXYS PALLIDUS* ESTABLISHMENT IN FILBERT ORCHARDS OF OREGON

ABSTRACT

A French strain of *Trioxys pallidus* was released in the filbert orchards of the Willamette Valley during 1984-1986 seasons. The rate of parasitization of these parasitoids was assessed by sampling a total of 13 orchards in 1987 and 30 orchards in 1988 and assessing for incidence of parasitization, orchards were sampled twice per year, once during June-July and once during September- October. Data show that the parasitoid has established in 11 out of 30 orchards, some with high populations. The level of parasitiation in Twedt Orchard during 1987 was 17%, which increased to 38.4% in fall of 1988. Similar trend was found in other orchards where the parasitoid was established. Data also show that *T. pallidus* is now moving to other adjoining orchards, although insecticide sprays appear to be the major hinderance.

INTRODUCTION

Trioxys pallidus Haliday an Aphidiid parasitoid was imported from Europe and released as adults and mummies against the filbert aphid, Myzocallis coryli (Goetze) at different locations in the Willamette Valley of Oregon since 1984. Releases were made in eight counties at thirty different sites (Messing and AliNiazee 1989, Cohn 1989). Preliminary establishment data showed that the parasitoid was active at many different sites and had improved its synchrony with the aphid phenology (Cohn 1989). Since differential survival was found in various released orchards, further understanding of establishment, distribution and efficacy patterns was necessary. A detailed investigation of all release sites was felt desirable and the data collected from these studies are reported here.

METHODS AND MATERIALS

During 1987, areas where the parasitoid was released earlier were selected for detailed studies. Climatically, all sites were similar and were located within a 120 mile istance, north to south in the Willamette Valley. Periodic sampling was conducted in all thirty filbert orchards, out of these, twenty six orchards were regularly sprayed and four were untreated. Each orchard was sampled twice a year, once during summer (June-July) and once during fall (September-October). The sampling timing corresponded to the peak aphid activity periods under field conditions. The sample dates were 18 June through 31 July during summer and 15 September through 10 October during fall. In each sample (which were sampled randomly), ten trees close to the release sites were sampled and ten twigs per tree were sampled covering the entire tree at about four to seven feet above the ground. Four leaves per twig were counted for aphids and _T. pallidus_, number of mummies and unparasitized aphids were recorded. The level of parasitization were determined by the formula: Total number of mummies / total number of aphids plus mummies X 100. The levels of parasitization was used as an indicater of establishment. The aphid population (comprising of 3rd and 4th instar and adults) and parasitized aphid (mummies) were counted in the field in order to avoid problems associated with bringing them into the laboratory.

The parasitized aphids normally tend to move to the edges of the leaves and stay close to the base of leaf petiole or move to woody portion of plant (van den Bosch 1962). This may have reduced the levels of parasitization found on the leaves. However, it was impossible to estimate those mummies which may have formed away from leaves in protected areas. Attempts were made to count all mummies except those which were ripped open by predaceous insects.

During the 1988 season, two changes were made in sampling procedures. First, the samples were collected randomly from the whole orchard blocks near the released sites, and second, only five trees per orchard were selected randomly for sampling. In addition to this regular sampling, one neighboring orchard (3/4 mile away from release site of the Twedt Orchard) was also sampled in the same fashion for assessing parasitoid dispersal and distribution.

RESULTS

All sites where T. pallidus were released during the past 4 years are shown in Table I-1 and Figure 1. The number and stage released are also given. The parasitization records as determined by the current study, are shown in Table I-2. Out of the 13 orchards sampled during 1987, the parasitoid was found at 8 sites indicating over 61% recovery from released sites. There appeared to be some differences in the rate of parasitization during spring and fall months, however, once the establishment has occurred, the parasites were found during both times. The level of parasitization was 18.5% and 16% at Twedt Orchard, for the spring and fall counts, respectively in 1987. In other orchards, the rate of parasitization was low, generally below 5% in both spring and fall months. Although the rate of parasitization in Twedt Orchard was less than 20%, but the aphid density was reduced substantially between 1985 and 1987 (down from ca. 100 aphids/leaf to <3 aphids/leaf) in the south side of the orchard and no aphid damage was noticed in this orchard.

All the study orchards were resampled during 1988 and the parasitoid recovery data are given in Table I-3. As mentioned earlier, in 1988 the sampling was extended to the whole orchard rather than sampling only around the release sites to assess the parasitoid dispersal besides

TABLE I-1 SITE AND FIELD RELEASES OF <u>TRIOXYS PALLIDUS</u>

Orchard Name	Location	County	Year Released	No. Released
Twedt	Corvallis	Benton	1985	6800A
Calef	Coburg	Lane	1985	300A
Simonson	Bellfountain	Benton	1985	300A
Gray	Albany	Linn	1985	400A
Buchanan				
a.	Bellfountain	Benton	1984	150A
b.	Bellfountain	Benton	1985	6300A
Knittel	Kiger Island	Benton	1985	4000A
Lemert	Junction city	Lane	1984	2350A
Duncan	Sherwood	Washington	1987	70A 100M
Newton	Dever Conner	Linn	1987	185A 25M
Abraham	Albany	Benton	1984	15A

Table I-1 (Continued)

Adelman	Brooks	Marion	1985	300A
Malone	Amity	Yamhill	1984	400A
Bush	Fern Ridge Dam	Lane	1984	1850A
Richard	Canby	Clackamas	1987	140A 75M
Peter	Willsonville	Yamhill	1987	185A 360M
Dennis	Dayton	Yamhill	1987	170A 350M
Huffman	Newburg	Yamhill	1987	435A 260M
Bestwick	Newburg	Yamhill	1987	245A 160M
Pierce	Newburg	Yamhill	1987	355A 160M
Skene	Dundee	Yamhill	1987	95A 100M
Mitchell	Newberg	Yamhill	1987	235A 210M

Table I-1 (continued)

Paul	Dever Conner	Linn	1987	250A 100M
Judy	Bellfountain	Benton	1987	80A
Winnie	Mc Minnville	Yamhill	1986	600M
Mark	Yamhill	Yamhill	1986	6A 700M
Jay glatt	Woodburn	Marion	1986	60A 200M
Phil	Gaston	Washington	1988	150A
Blake	Salem	Polk	1988	100A
Smith	Monroe	Lane	1987	200A
Castillano	Bellfountain	Benton	X	X

A: no. of adults released

M: no. of mummies released

X: no information

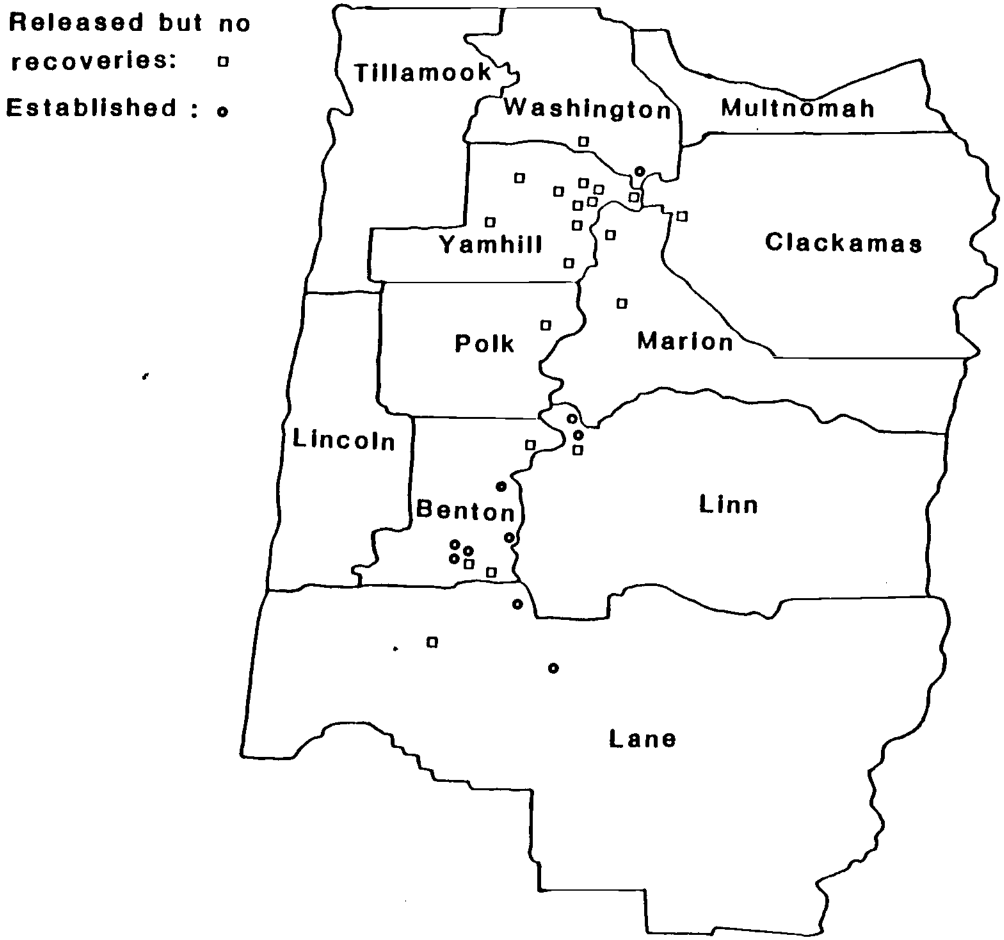


Fig.1. Map of Willamette Valley, Oregon, showing location of orchards where _Trioxys_ _pallidus_ was released and has established

TABLE I-2 INCIDENCE OF <u>TRIOXYS</u> <u>PALLIDUS</u> IN ORCHARDS SAMPLED DURING 1987

Orchard Name	Spring		Fall	
	No. of Aphids +Mummies	Rate of Parasitization (%)	No. of Aphids +Mummies	Rate of Parasitization (%)
Twedt	878	18.5	488	16.0
Calef	434	3.0	194	4.6
Simonson	590	0.0	643	0.5
Gray	2340	0.0	270	0.0
Buchanan	336	0.3	638	0.5
Knittel	11	0.0	365	4.1
Lamert	16	0.0	379	0.0
Duncan	623	0.2	231	0.9
Newton	17229	0.0	1736	0.1
Abraham	370	0.0	201	0.0
Adelman	2311	0.0	1367	0.2

Table I-2 (Continued)

Malone	3856	0.0	1763	0.0
Bush	4132	0.0	2917	0.0

TABLE I-3 INCIDENCE OF *TRIOXYS PALLIDUS* IN ORCHARDS SAMPLED DURING 1988

Orchard Name	Spring		Fall	
	No. of Aphids +Mummies	Rate of Parasitization (%)	NO. of Aphids +Mummies	Rate of Parasitization (%)
Twedt				
a. South	169	24.9	492	38.4
b. North	3507	16.1	437	42.1
c. West	5041	7.8	637	23.5
d. East	8307	5.0	245	38.8
Calef	220	24.1	872	10.1
Simonson	701	34.5	401	8.5
Gray	4261	3.3	240	11.7
Buchanan	654	31.6	749	7.1
Knittel	108	29.6	568	3.5
Lemert	87	23.0	509	1.4
Duncan	308	2.6	175	5.1

Table I-3 (Continued)

Newton	135	1.5	10580	0.2
Abraham	112	0.0	73	0.0
Adelman	104	0.0	1121	0.0
Malone	1939	0.0	112	0.0
Bush	304	0.0	1954	0.0
Richard	43	0.0	39	0.0
Peter	1021	0.0	91	0.0
Dennis	223	0.0	349	0.0
Huffman	337	0.0	516	0.0
Bestwick	403	0.0	80	0.0
Pierce	244	0.0	137	0.0
Skene	355	0.0	87	0.0
Mitchell	1647	0.0	524	0.0
Paul	71	0.0	43	0.0
Cohn	48	18.8	18	5.6

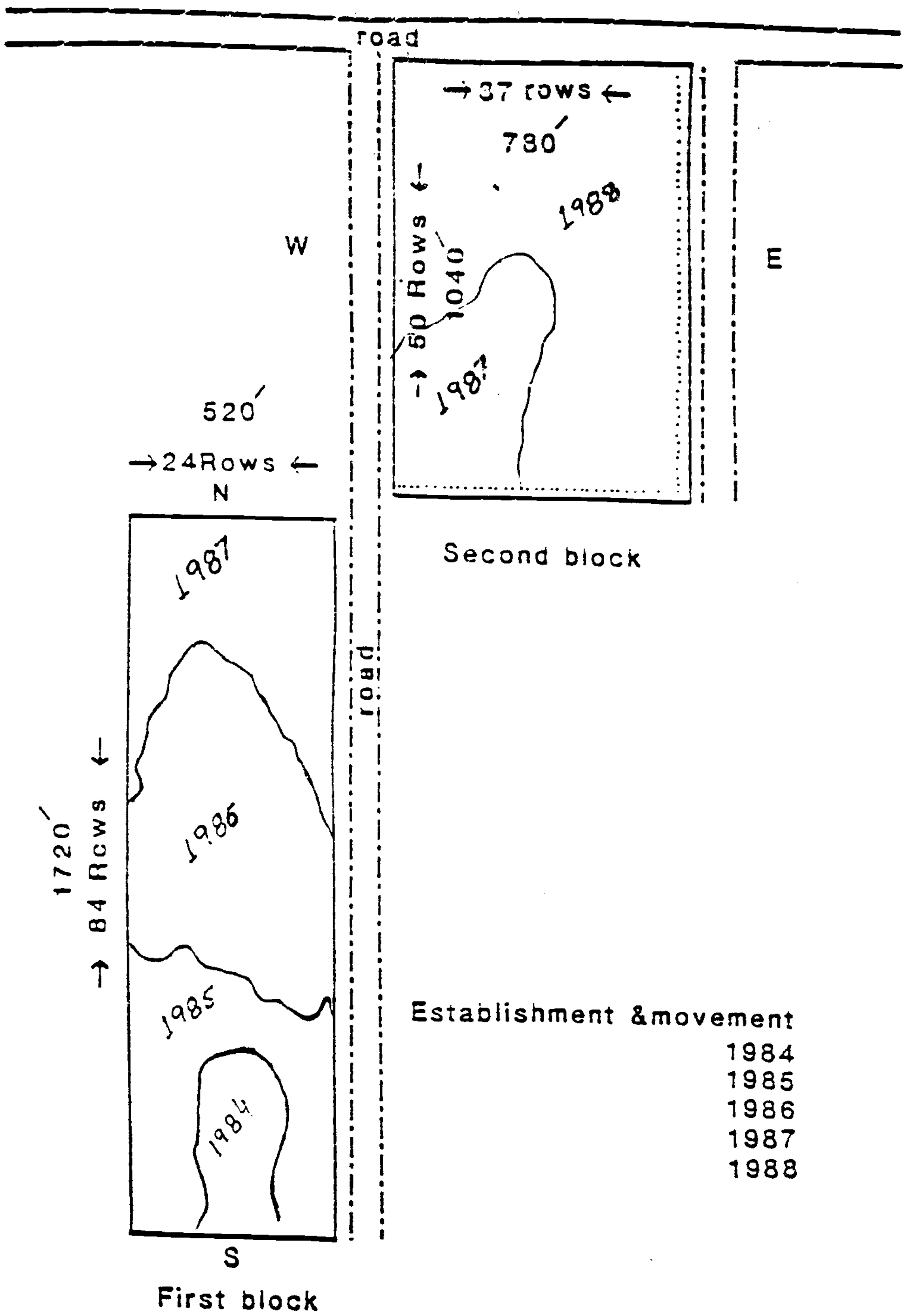
Table I-3 (Continued)

Winnie	736	0.0	227	0.0
Mark	201	0.0	79	0.0
Jay	264	0.0	397	0.0
Phil	Released in spring 1988		1075	0.0
Blake	Released in fall 1988			
Smith	Released in 1987, but no information			
Castillano	737	0.3	676	0.4

establishment. In Twedt Orchard, which was one of the best examples of parasitoid activity, the release site was the south half of the orchard, where percent parasitization was 16% in fall, 1987. In the spring and fall of 1988, the rate of parasitization were, respectively, 24.9% and 38.4% in the south half of the orchard and 16.1% and 42.1% on the north side of the orchard where no parasitoids were released before. This indicates the increasing trend of parasitization and multiplication in the south half of the orchard and good dispersal to the north half.

The movement of T. pallidus in Twedt Orchard since first released in 1984 to present is shown in Figure 2. Although initial establishment was noticed in 1985, one year after release, it took 2-3 years to build up populations and move northward. By the end of the 1988 season it, neverthless, had moved all over the entire block of filberts and established large populations about a mile or so away from the original release site. The rate of parasitization also increased to over 42% by 1988, and aphid populations ($\bar{x}$ aphid/leaf = 1.7) were much below the economic threshold. The parasitoid population also was established in the east and west sides of another orchard just across the road (see Figure 2). Both these blocks were surveyed and parasitization rates calculated during 1988 year. A similar pattern of parasitization was noticed in both

Fig.2 Map showing movement of Trioxys pallidus in Twedt Orchard



blocks; the parasitization rates were low during spring, 7.8% and 5% for west and east blocks, respectively, and increased markedly in the fall, 23.5% and 38.84%, respectively for the west and east blocks. The five year impact of T. pallidus releases on aphid density in Twedt Orchard is shown in Figure 3, which shows a marked increase in the density of T. pallidus and depression of the host density.

The parasitoid parasitization of nine orchards are given in Figures 4-12. Data in the figures show that the parasitization rates were higher in 1988 than in 1987. In some orchards, the rate of parasitization in the fall was more than in the spring (Twedt, Gray and Duncan), while others (Newton, Lemert, Knittel, Buchanan, Simonson and Calef orchards) had a higher rate of parasitization in the spring than fall.

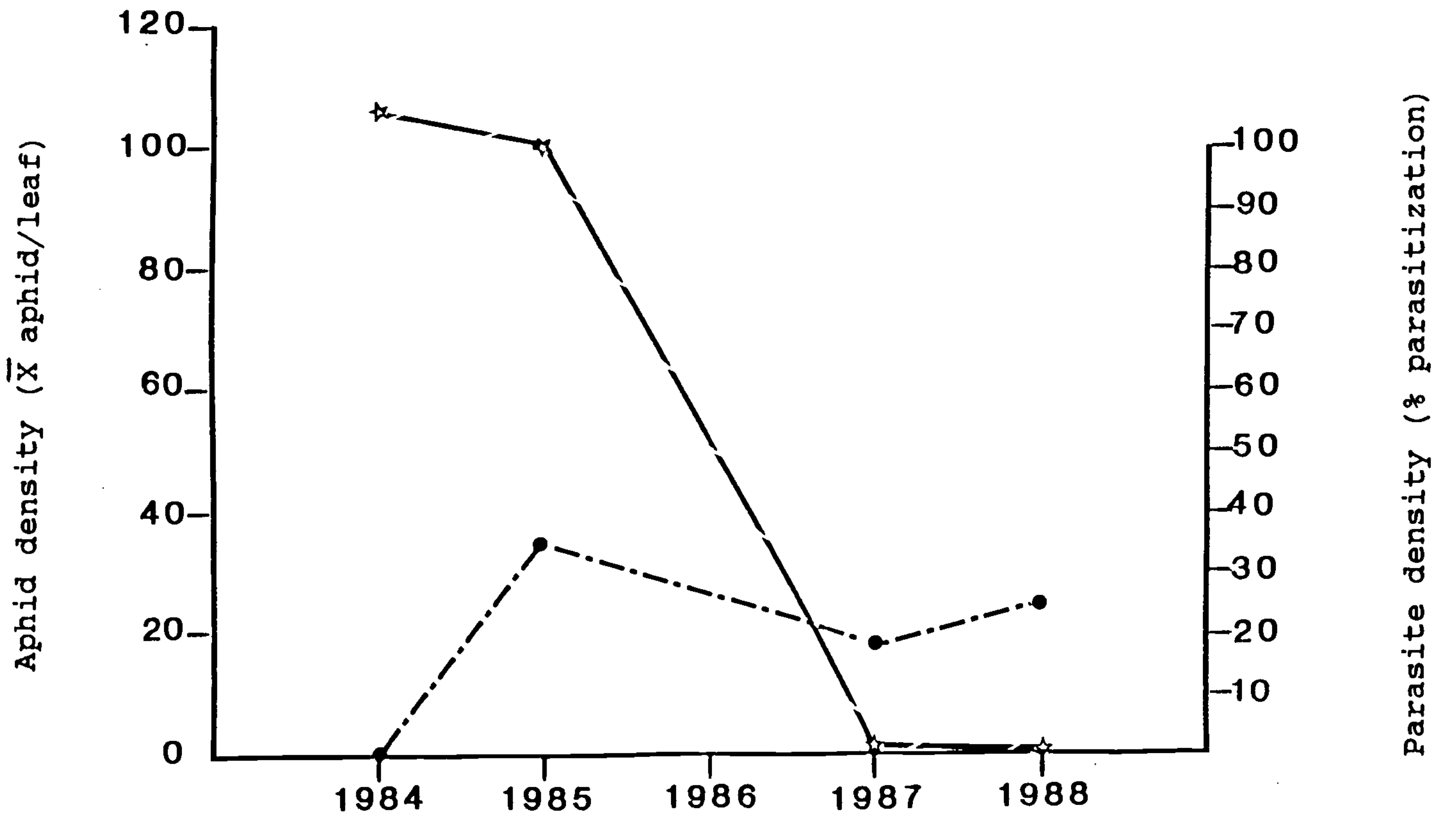


Fig.3. Aphid density at Twedt Orchard (south side) before and after releases of <u>Trioxys pallidus</u>. (Counts taken during peak seasonal activity period)

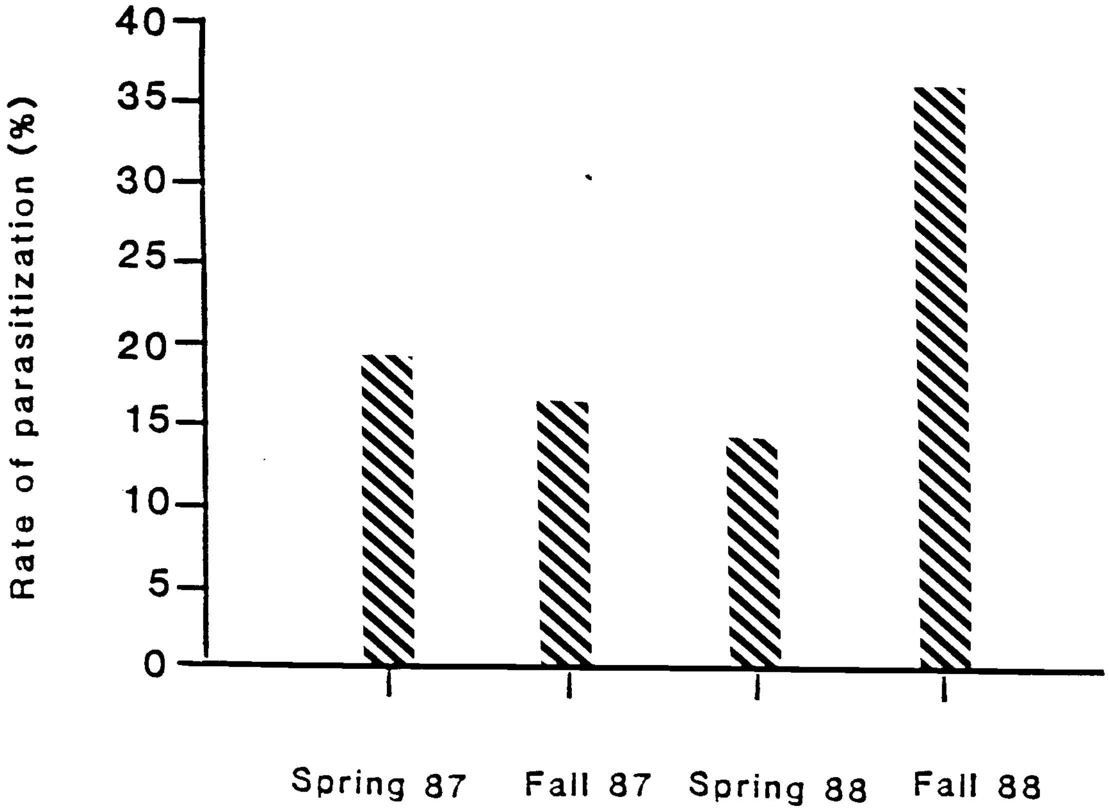


Fig.4. Rate of parasitization of M. coryli by T. pallidus in Twedt Orchard during spring and fall of 1987 & 1988

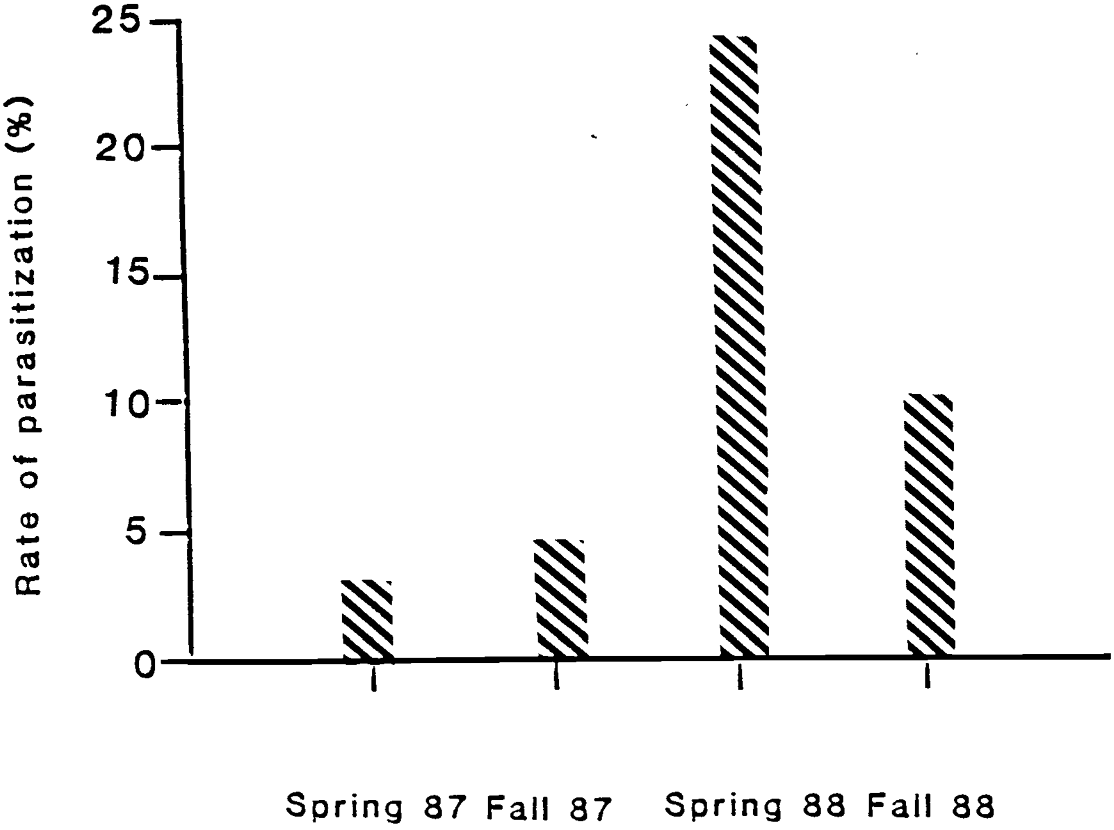


Fig.5. Rate of parasitization of M. coryli by T. pallidus in Calef Orchard during spring and fall of 1987 & 1988

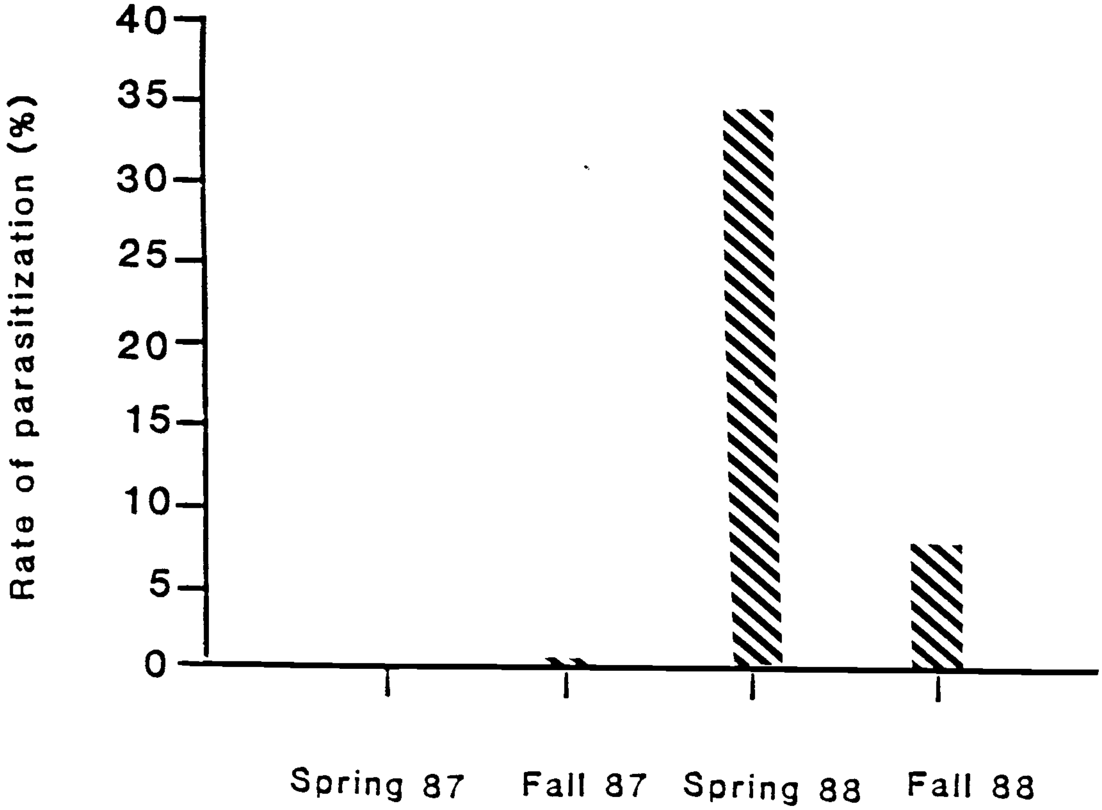


Fig.6. Rate of parasitization of M. coryli by T. pallidus in Simonson Orchard during spring and fall of 1987 & 1988

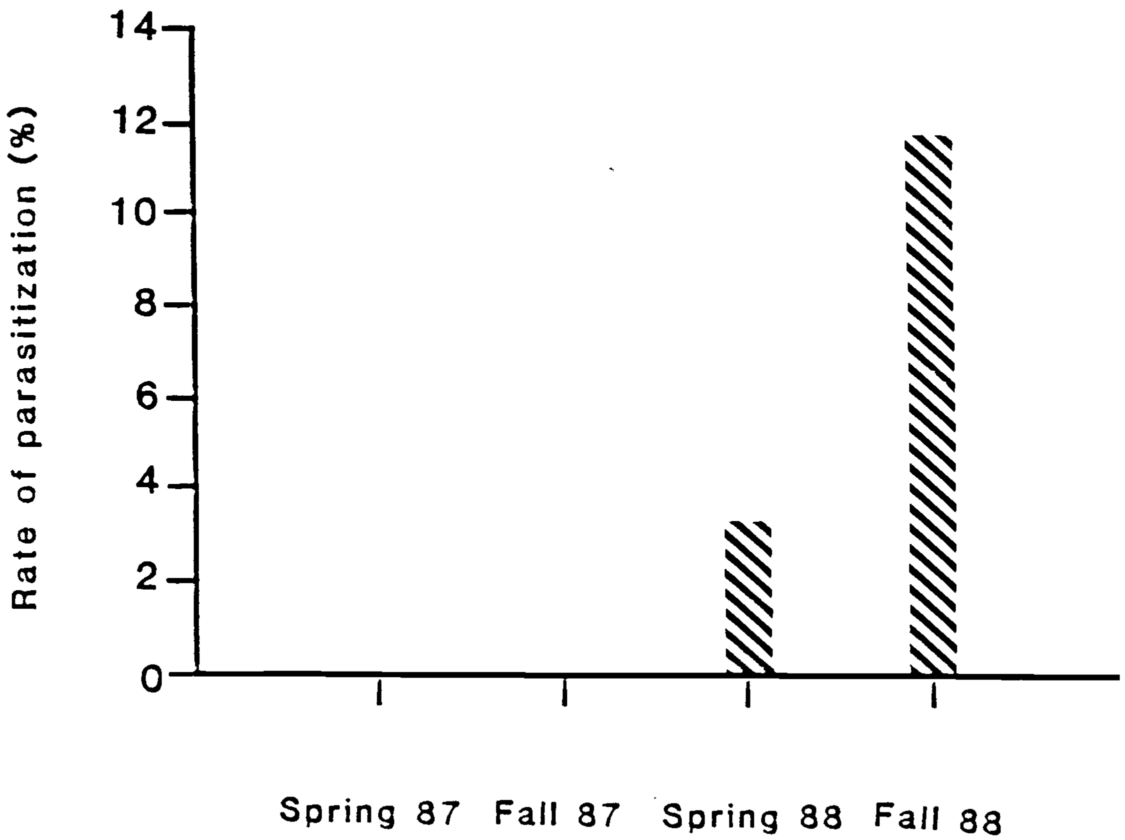


Fig.7. Rate of parasitization of M. coryli by T. pallidus in Gray Orchard during spring and fall of 1987 & 1988

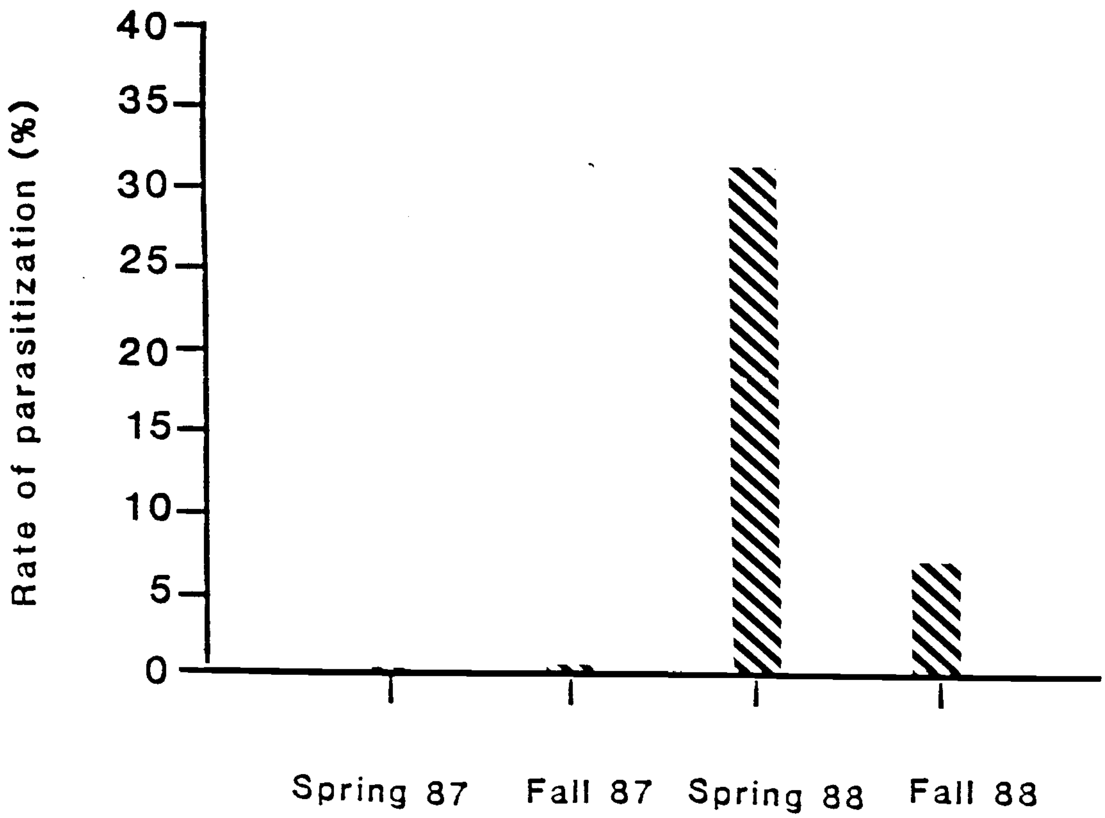


Fig.8. Rate of parasitization of M. coryli by T. pallidus in Buchanan Orchard during spring and fall of 1987 & 1988

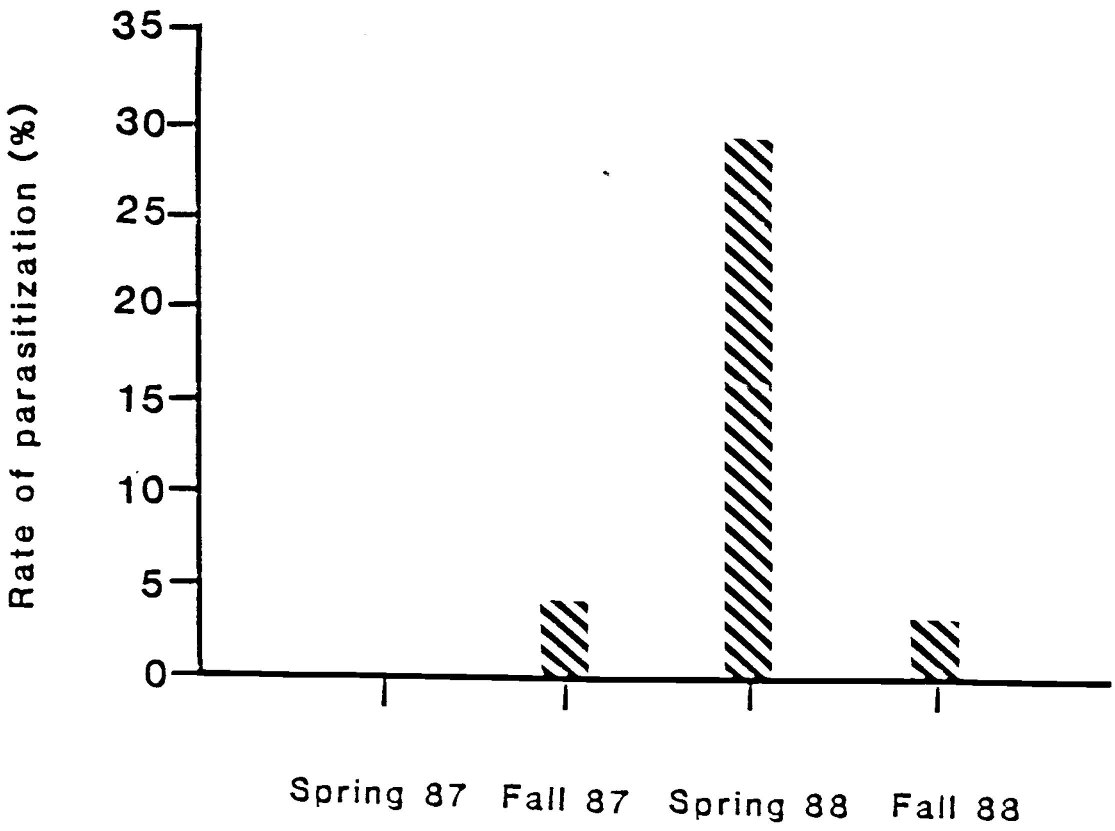


Fig.9. Rate of parasitization of M. coryli by T. pallidus in Knittel Orchard during spring and fall of 1987 & 1988

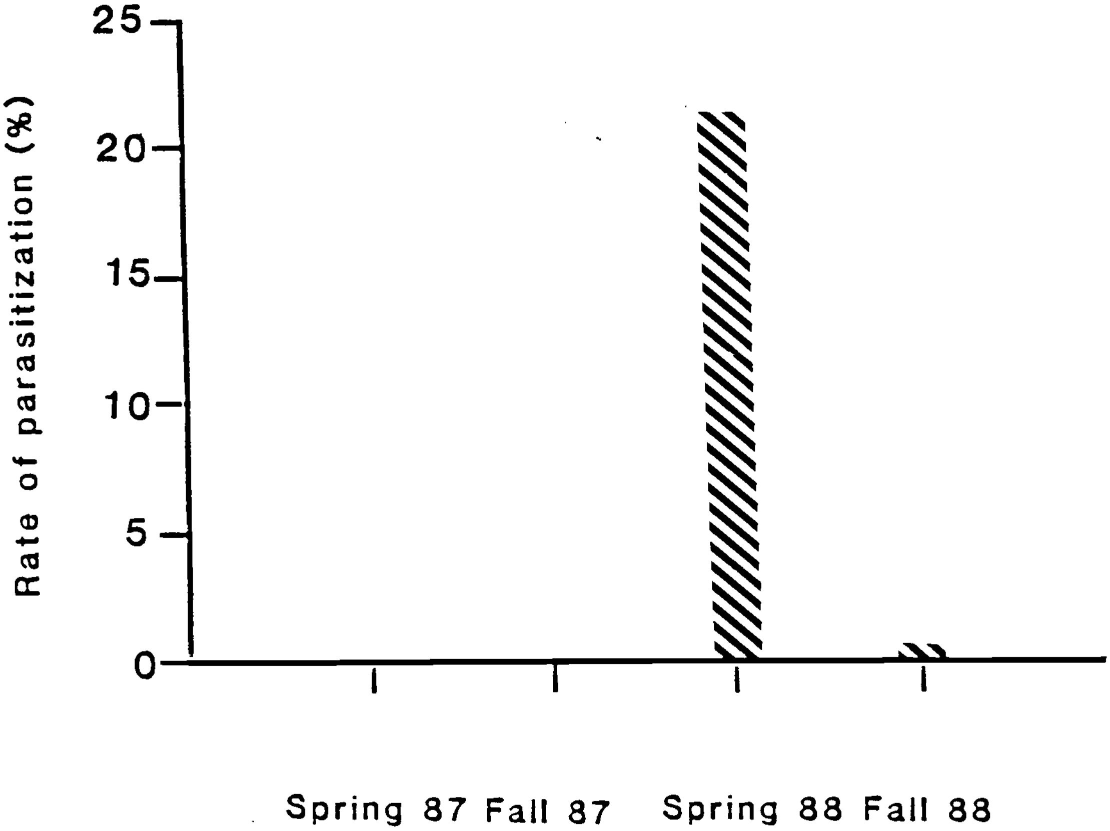


Fig.10. Rate of parasitization of M. coryli by T. pallidus in Lemert Orchard during spring and fall of 1987 & 1988

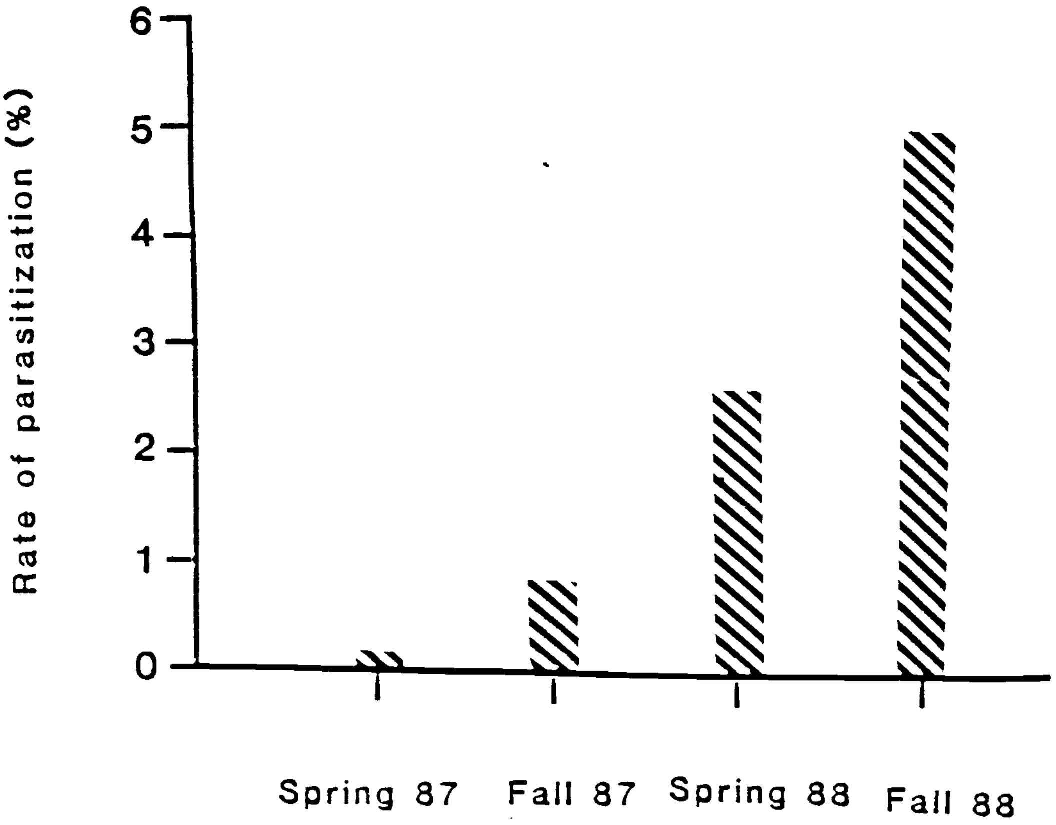


Fig.11. Rate of parasitization of M. coryli by T. pallidus in Duncan Orchard during spring and fall of 1987 & 1988

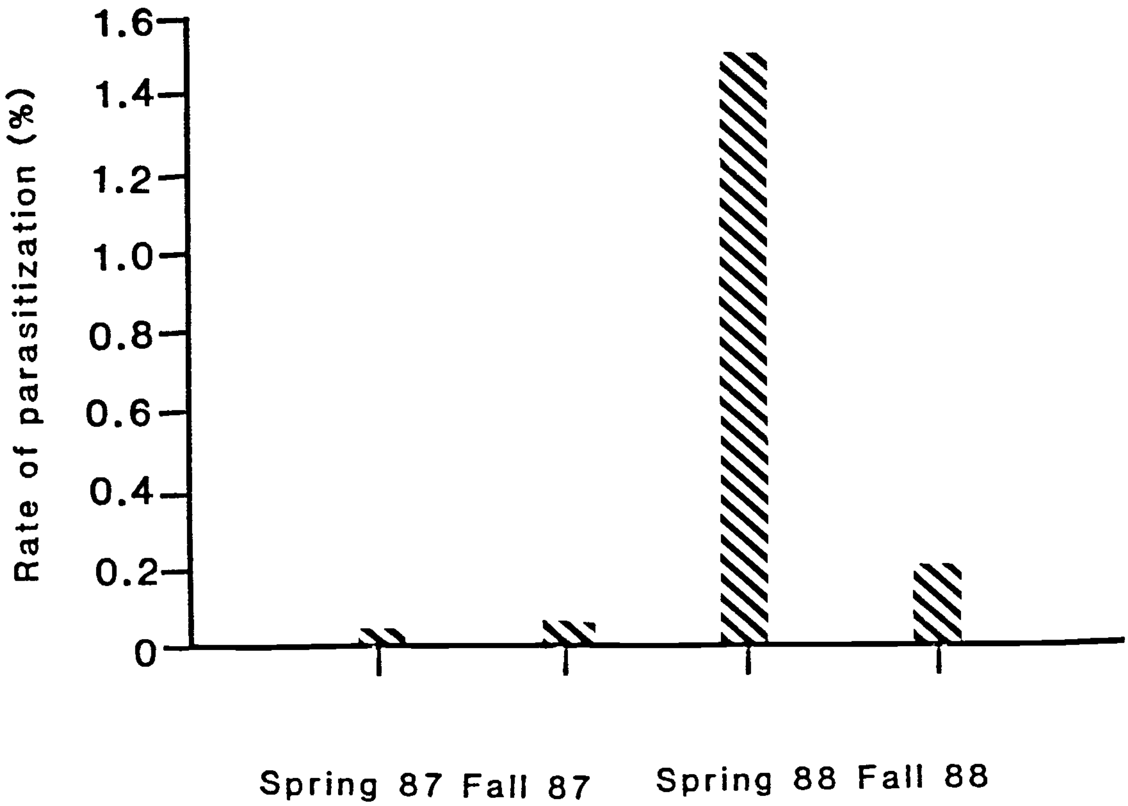


Fig.12. Rate of parasitization of M. coryli by T. pallidus in Newton Orchard during spring and fall of 1987 & 1988

DISCUSSION

Because of the limited number of parasitoids available and the lack of mass production facilities, only a small number of T. pallidus were released at different sites during 1984 and 1985 seasons (Table I-1). Later releases were also small. Twedt Orchard was the highest parasitoid released orchard, therefore the resultant establishment at this site is not surprising. Beirne (1975) demonstrated that in many classical biological control programs the average number of natural enemies released had an influence on the probability of establishment. He reported that the median numbers released of all 159 introduced species (excluding species with undetermined or unclear results) in various biological control programs was about 5,000 individuals. The median was about 31,200 for the 44 species that became established. The establishment rates of the species released in totals of under 5,000, were 10% (9 of 98) between 5,000 and 31,200, were 40% (13 of 33); and over 31,200 were 78% (22 of 28). This suggests that the greater the number released the greater the likelihood of successful colonization, and that if the numbers were below some minimum (about 5,000 individuals) the probability of establishment was small. This implies that some of the failures of the past could be successes in the future if the species is reintroduced in sufficiently large quantities to achieve establishment. A minimum "inoculation charge" is needed if reasonable chances for parasite establishment are to be expected (van den Bosch et al. 1958).

In the present study, it appears that the parasite activity was generally low in the spring and high in the fall, although, there were exceptions. During 1984 none of the orchards received a sufficient number of parasitoids causing poor immediate establishment. In 1985, about 5000 adults were released in two orchards, which did not show any parasitization during the spring and fall of 1985, but in some parasitization was noticed in the spring of 1986.

A linear regression analysis was used to describe the relationship between the number of T. pallidus released and the rate of parasitization at the sites where establishment was evident. The relationship for the number of parasitoids released and the rate of establishment was significantly different ($P<0.01$, $F= 7.62$, df 1,7). The analysis shows that there is a positive relationship between the number of parasitoid released and the percent parasitization, although the correlation is weak. It nevertheless, tends to support Beirne's (1975) contention that the higher parasitoid numbers released enhance the chances of parasitoid establishment.

Data (Table I-2) show that except for Twedt's, all other orchards were parasitized at less than the 5% level during most of the study years. Beside the low numbers released, this lack of rapid build up may be related to a number of biological factors. Messing (1986) postulated that frequent killing of parasitized aphids by generalist predators like coccinellids, chrysopids, etc. is partly to blame for the poor showing of T. pallidus in many orchards. It is also believed that the application of insecticides in commercial orchards would have an adverse impact on the level of parasitization. The pesticide sprays could have at least two negative effects on the parasitoid. First, the density of the parasitoid would be reduced due to direct mortality (Section IV) and second, periodical depletion of aphid populations available for parasitoids could reduced food supplies thus causing indirect mortality of the natural enemy. It appears that T. pallidus is succesfully facing all these hardships in commercial orchards of Oregon.

Table I-3 shows the overall distribution and establishment trends of T. pallidus in the Willamette Valley. Based on the wide distribution of the parasitoid, their ability to disperse on their own (at least a few miles), and rapid reproductive potential under field conditions, it appears that many orchards of the Willamette Valley could have a substantial number of this parasitoid in the near future. The data shown here does suggest, however, that low number of parasitoids released per site had a delaying effect on establishment. Therefore, parasitoid numbers might be an important criteria to consider for future releases.

Based on the distribution pattern of T. pallidus in Twedt Orchard (Table I-3) a successful colonization is apparent. The increased parasitization in both orchards (north and south) during spring 1988 apparently is the result of the increased level of parasitization during fall 1987, and the early emergence of adults from diapause in the spring. It appears that the weather conditions were ideal for spring emergence of T. pallidus during 1988. The relatively low degree of parasitization on the west and east sides of the second block of Twedt Orchard during the same period suggests the lack of presence of overwintering mummies in these blocks. So the parasite activity noticed during summer and fall was probably a result of adult wasps moving in from the south block. In the 1989 year this situation could be ameliorated because of the presence of a large number of overwintering parasitoid mummies. A broad increase in parasite population at Twedt Orchard was observed during fall 1988 (Table I-3), which was probably a result of exponential growth of the parasitoid after initial hurdles were removed. van den Bosch (1962) reported a similar situation in California with walnut aphids.

The parasitoid population trends in the Gray and Duncan Orchards were similar to Twedt's, although, the numbers were much lower. As mentioned earlier, this difference in the parasite activity could be related partly to the number of parasitoids released per site. A different population dynamic patterns were noticed in Calef, Simonson, Buchanan, Knittel, Lemert and Newton orchards. In contrast to Twedt's, the parasitoid populations in most other orchards declined gradually till fall 1988, and provide a lesser degree of aphid suppression. This downward trend was probably caused by many factors including predators, hyperparasitoids, other generalist predators and perhaps weather, and cultural practices (AliNiazee 1983a, 1985; Messing 1982 and van den Bosch 1968). These commercial orchards were sprayed three time during the season for aphid and filbertworm control (Table I-4).

As the data presented in the next section will show these sprays could have devastating effects on adult parasitoid. Had it not been for the aestivating mummified pupae of the parasitoid, the continuum would have been broken, resulting in a complete failure. The low host level found in July and August also influenced the levels of parasitization. Twedt Orchard, on the contrary, was sprayed only once for filbertworm during summer providing ample opportunities for parasitoid survival and increased activity. So it appears that the pest management methodology used in a filbert orchard would increase or decrease the chances of _T_. _pallidus_ survival.

TABLE I-4 PESTICIDE USE PATTERN WHERE _TRIOXYS_ _PALLIDUS_ WAS RELEASED

Orchard Name	Size (acre)	Age (years)	Insecticide Used 1985	1986	1987	1988
Twedt	20	8-62	F	F	F	F
Calef	50	6-40	-	Ch	Ch	Ch
Gray	22	64	Ch	D	Ch	Ch
Lemert	10	10-35	C	D	Ch	Ch
Adelman	12	20	Ch	F+Ch	F+Ch	Ph
Malone	60	6-65	-	Ch	Ch+F	Ch
Bush	30	17	C+Ch	C	Ch	F+Ch
Peter	15	45	D	F	Ch	F
Abraham	20	62	Abondoned since 1972			

* C=carbaryl Ch=chlorpyrifos D=diazinon F=fenvalerate
Ph=phosalone -=none

A more judicious and planned use of insecticide as practiced at Twedt's may prove to be a model for other growers interesting in conserving T. pallidus.

In brief, it appears that T. pallidus is now well established in many orchards of the Willamette Valley, and suppressing the population of filbert aphids. Our data combined with previous work (Messing 1986, Cohn 1989) confirms that this insect has all the good attributes of a successful biological control agent, such as high searching ability, high reproduction rate, host specificity and host synchronization and summer diapause. If encouraged by proper cultural and management practices, it has the ability to rapidly move into other adjoining commercial orchards on its own, thus establish new populations to control filbert aphids.

REFERENCES CITED

AliNiazee, M. T. 1983a. Carbaryl resistance in the filbert aphid (Homoptera: Aphididae). J. Econ. Entomol. 76:1002-1004.

AliNiazee, M. T. 1985. Pests of hazelnuts in North America. A review of their bionomics and ecology. Proc. Intern. Congress of hazelnuts, Avellino, Italy. Sep. 1983, pp. 463-476.

Beirne, B. P. 1975. Biological control attempts by introduction against pest insects in the field in Canada. Can. Entomol. 107: 225-236.

Cohn, J. 1989. Synchronization of Trioxys pallidus with its host, Myzocallis coryli (Goetze) in filbert orchards of Oregon. M.S. thesis, Oregon State Univ. Corvallis. in preparation.

Messing, R. H. 1982. Biology of the predator complex of the filbert aphid, Myzocallis coryli (Goetze), in western Oregon. M.S. thesis, Oregon State Univ. Corvallis.

Messing, R. H. 1986. Classical Biological Control of the filbert aphid, Myzocallis coryli (Goetze) (Homoptera: Aphididae) in Western Oregon. Ph.D. thesis, Oregon State Univ., Corvallis.

Messing, R. H. and M. T. AliNiazee. 1989. Importation and establishment of Trioxys pallidus (Hym.: Aphidiidae) on filbert aphid, Myzocallis coryli (Hom.: Aphididae) in western Oregon, U.S.A. Entomophaga, in press.

van den Bosch, R., E. I. Schlinger, E. J. Dietrich, K. S. Hagen And J. K. Holloway. 1958. The colonization and establishment of imported parasites of the spotted alfalfa aphid in California. J. Econ. Entomol. 52: 136-141.

van den Bosch, R., E. I. Schlinger, and K. S. Hagen. 1962. Initial field observations in California on Trioxys pallidus, (Holiday),a recently introduced parasite of Walnut aphid. J. Econ. Entomol. 55: 857-862.

van den Bosch, R., Stern, V. M. 1962. The integration of chemical and biological control of arthropod pests. Annu. Rev. Entomol. 7: 367-386.

van den Bosch, R., C. A. Ferris, L. K. Stromberg, L. A. Falcon, T. F. Leigh, R. E. Stinner and L. K. Etzel. 1968. A comparison of season-long cotton-pest control program in California during 1966. J. Econ. Entomol. 61: 633-642.

IV. RELATIVE TOXICITY OF SOME COMMONLY USED PESTICIDES TO *TRIOXYS PALLIDUS* IN FILBERT ORCHARDS OF OREGON

ABSTRACT

Four organophosphate (Metasystox-R, Zolone, Diazinon and Lorsban) and one synthetic pyrethroid (Pydrin) insecticides (which are most commonly used pesticides in filbert orchards of Oregon) were tested against adults of a field and a laboratory populations of *Trioxys pallidus* Haliday. A Comparison of LC50 and LC95 values showed no significant differences in the susceptibility of these two populations to all organophosphate insecticides, however, a low level build up of tolerance against Pydrin was evident. The field population required approximately a 2 fold higher rate than the laboratory susceptible population for similar level of mortality. Metasystox-R was highly toxic to both populations with LC50 values of 1.13 and 1.06 ppm, respectively for the field and the laboratory population. Lorsban was the least toxic with LC50 values of 28.31 and 23.39 ppm, respectively for the field and the laboratory populations.

INTRODUCTION

Insecticide resistance in pest species has reached alarming proportions throughout the world (Georghiou 1986). Nearly 450 species are now reported to be resistant to insecticides. The incidence of resistance in the beneficial species is, on the contrary, relatively low and slow to occur. In the filbert system of Oregon, the filbert aphid, Myzocallis coryli (Goetze) has developed resistance to carbaryl (AliNiazee 1983b) and a number of other insecticides (Katunda and AliNiazee 1989).

No resistance was noticed in predatory or parasitic insects although different susceptibility to insecticides was recorded (Messing 1985). A French strain of Trioxys pallidus Haliday which was released in Oregon against the filbert aphid, has shown variable results of parasitization in the commercial orchards. In addition to cultural and management practices, the level of parasitization is most directly related to the insecticide use pattern in individual orchards.

Thus the purpose of the study reported here was to develop the base line data on susceptibility of T. pallidus to most commonly used insecticides in the filbert orchards of Oregon and to determine the degree of development of resistance in the field populations of this parasitoid. Other studies have shown that T.

pallidus is capable of developing resistance to pesticides (Hoy and Cave 1988) in other crops, and we presumed that a similar situation may be occurring in filberts. The base line data would be highly useful in detecting future development of resistance in this species.

METHODS AND MATERIAlS

ORCHARDS:- A general survey of the orchards where T. pallidus was released and had been established suggested that Twedt Orchard (where parasitoids were released in 1985) was the most convenient site from which we could collect a large number of parasitoid adults for insecticide toxicity experiments. Moreover, this orchard was continuously sprayed with Sevin (one spray per year) and Pydrin (two sprays per year) since 1985, thus continually exposing the parasitoid to these two pesticides.

The orchard was divided into two blocks. The first block was the one in which the parasitoid was released in 1985. The parasitoid spread to the second block (ca .75 mile apart) on its own (see Figure 2) during 1987 and 1988. The adults needed for the present study were collected from both blocks, brought to the laboratory during the end of May and early June 1988, and were allowed to multiply on laboratory reared aphids. T. pallidus adults were collected randomly from leaves from all over the orchard and attempts were made to avoid the chance collection of clonal populations. By the end of August 1988, large numbers of field collected adults were available in the greenhouse cultures to conduct the experiments. Another population of T. pallidus was also reared in a separate green house. This population had never been exposed to any insecticides since they were imported to this country in 1984, and was assumed to be a susceptible population. The insecticide susceptibility data from this population was compared with Twedt's population to determine the degree of resistance development under field conditions.

INSECTICIDES:- A number of farmers were asked about their insect control program to find out the relative use of different pesticides in filbert orchards. Based on this information, four organophosphate (OP)and one synthetic pyrethroid (SP) insecticides were selected for toxicity tests. These included; oxydemetonmethyl (Metasystox-R 25EC, Mobay Chemical Company), fenvalerate (Pydrin 2.4 EC, Shell Chemical Co.), phosalone (Zolone 3 EC, Rhone-Poulenc Agric. Chemicals Co. Research Triangle Pank, N.C.) diazinon (Diazinon 50 WP, Ciba-Geigy), and chlorpyrifos (Lorsban 50 wp, Dow Chemical Co.) from OP group and fenvalerate (Pydrin 2.4 EC, Shell Chemical Co.) from SP group, (Table II-1). The test insecticides were disolved in acetone, and a minimum of five concentrations for each insecticide were prepared from a serial solution.

In the absence of baseline dosage-mortality data on the _T_. _pallidus_, different dosage concentrations were chosen for tests. These include, 0.001, 0.005, 0.01, 0.05 and 0.1 time the recommended field rate for each chemical. An untreated check comprising of only acetone

TABLE II-1 INSECTICIDES USED FOR EXPERIMENTS

Common name	Trade name and Formulation used	Recommended field rate 100 gals.	AI gm/L
oxydemeton-methyl	Metasystox-R, 25 EC	0.5 pt (144 ppm)	0.14
fenvalerate	Pydrin, 2.4 EC	0.66 pt (237.5 ppm)	0.24
phosalone	Zolone, 3 EC	1.5 pt (676 ppm)	0.68
diazinon	Diazinon, 50 WP	1.0 lb (600 ppm)	0.6
chlorpyrifos	Lorsban, 50 WP	3.0 lb (1800 ppm)	1.8

treated adults was also included.

BIOASSAYS:- The toxicity tests were conducted by collecting the mixed-age, T. pallidus adults of both sexes with an aspirator and putting them in glass jars (4x4x4 mm) treated with different treatment insecticides and capped with untreated polyester gauze. Approximately 0.5 ml solution of each insecticide concentration was placed in glass jars and the inside surface was thoroughly coated until the liquid disappeared. These jars were then left for drying at room temperature (24 ± 1°C) for 24 hours. Control jars were treated only with 0.5 ml acetone. A constant number of adults was used in each treatment, however, due to different survival rate and handling damage (like parasitoid getting stuck in honey solution or aspiration mortality) different number of adults (8-16) were tested in each replication. A 25% honey solution was supplied as food by applying to the sides of jars with a fine needle in streaks. All experiments were conducted at 18°C and 70% R.H. with a 16L:8D photoperiod.

The mortality was assesed 24 hours after treatment. In all tests adults were considered dead when they were unable to move their legs when proded with camel hair brush. Data were analyzed by using the Polo Computer Program (Russell et al. 1977), regression lines determined for each treatment, and mortality level determined. Resistance factors (RF) was calculated for each pesticide by dividing the LC50 and LC95 values of Twedt's population by same values obtained from a laboratory susceptible culture.

RESULTS

Data (Table II-2) show that all test insecticides were toxic to _T. pallidus_ and nearly one hundred percent adult mortality of both populations (a laboratory susceptible population and a field population obtained from Twedt Orchard) was observed when they were placed in treated jars at the field rates. Only Diazinon at 0.1x of field rate allowed 17.2% and 19.9% of the laboratory and the field population survival, respectively. No adult survival was noticed in jars treated with Metasystox, Pydrin, Zolone and Lorsban at 0.1x of the field rate. The LC50 values of all these five insecticides along with 95 % confidence limits and the slopes of dosage mortality lines for the parasitoid are presented in Table II-2.

A wide range of responses occurred when the adult parasitoid were tested against these different insecticides, for example, the LC50 values ranged from 1.06 ppm for Metasystox to 28.3 ppm for Lorsban (Figure 13, 14, 15, 16 and 17). The dosage / mortality curves of field and laboratory populations provided a comparison of the pesticide toxicities for both _T. pallidus_ populations. The slopes of the regression curve for both population were relatively flat but variable (Figure 18 and 19), suggesting a heterogeneous response. However, there was clearcut evidence of development of a low degree of tolerance to Pydrin in the field population.

TABLE II-2 COMPARATIVE SUSCEPTIBILITY TO INSECTICIDES OF TWO POPULATIONS OF TRIOXYS PALLIDUS (FIELD AND LAB) AT LC50 VALUES

Insecticide	Pop.	No. insects treated	LC50 & 95% (CL) (ug/g)	Slope ± SE	RF 50
Metasystox	Field	250	1.13 (0.67-1.78)	1.47 ± 0.23	1.1
	Lab	250	1.06 (0.62-1.70)	1.53 ± 0.25	1.0
Pydrin	Field	250	2.47 (1.50-3.83)	1.84 ± 0.33	1.9
	Lab	250	1.30 (0.78-1.99)	1.39 ± 0.21	1.0
Zolone	Field	250	9.13 (6.77-12.01)	2.03 ± 0.32	1.1
	Lab	250	8.14 (5.97-10.83)	2.22 ± 0.36	1.0
Diazinon	Field	300	20.94 (14.69-29.17)	1.60 ± 0.30	1.1
	Lab	300	18.73 (12.99-26.34)	1.71 ± 0.35	1.0
Lorsban	Field	250	28.31 (15.25-48.14)	1.88 ± 0.31	1.2
	Lab	250	23.39 (12.45-39.50)	1.75 ± 0.31	1.0

Lab: Laboratory, Pop: Population, RF50: LC50 field pop / LC50 lab pop

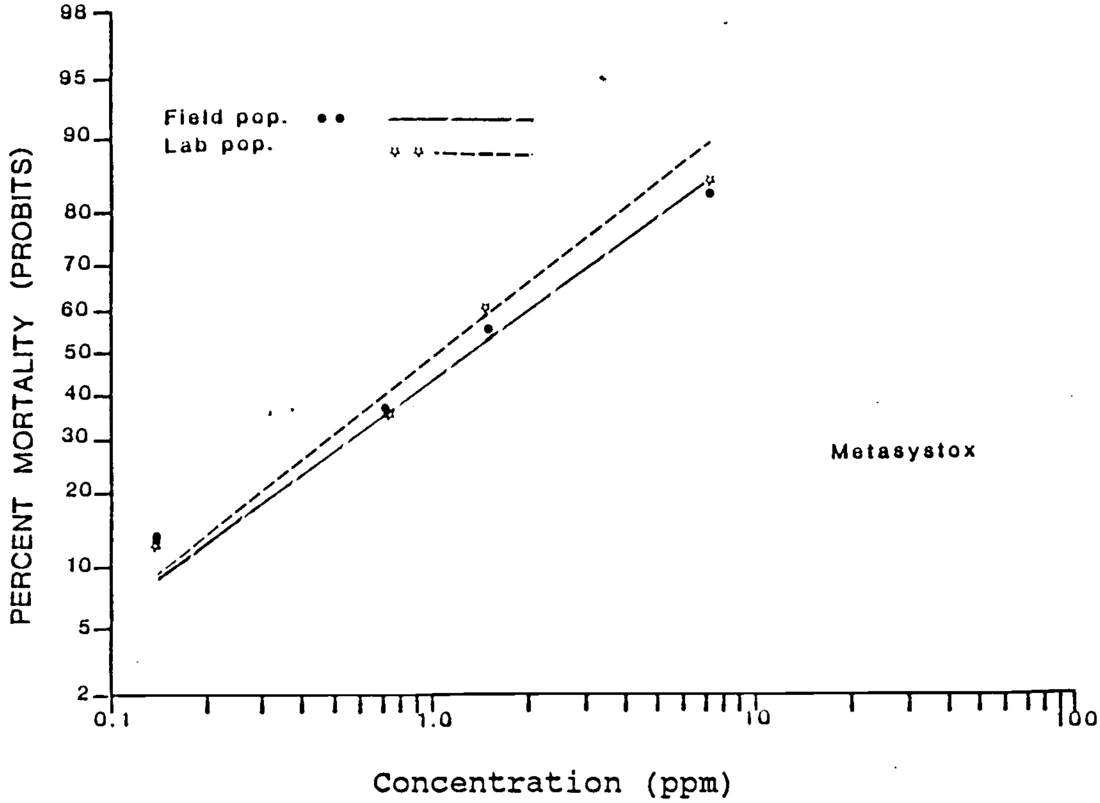


Fig.13. LDP lines of two populations of T. pallidus exposed to Metasystox-R

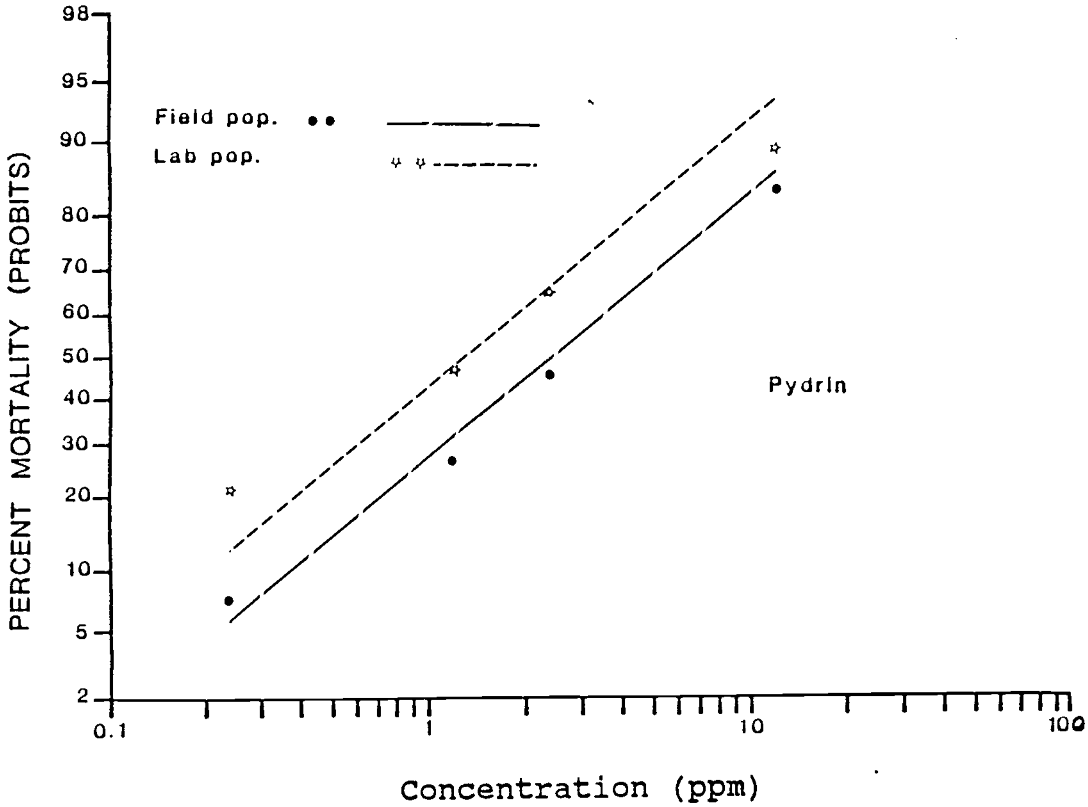


Fig.14. LDP lines of two populations of <u>T</u>. <u>pallidus</u> exposed to Pydrin

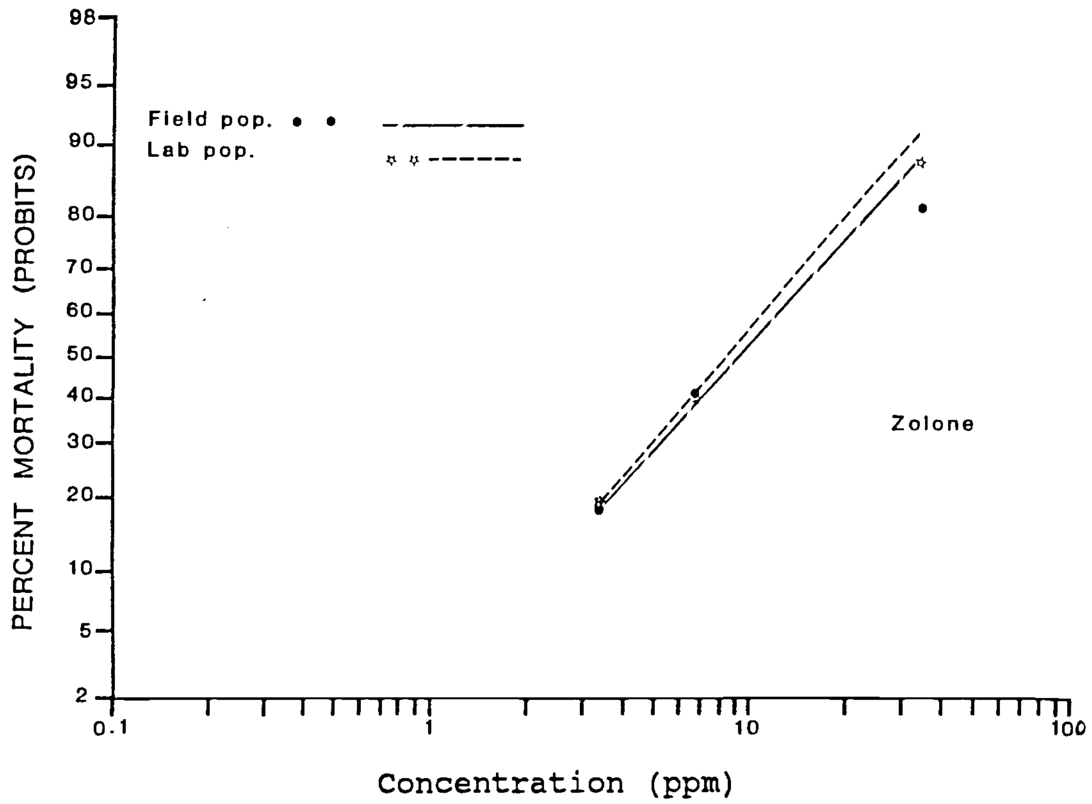


Fig.15. LDP lines of two populations of T. pallidus exposed to Zolone

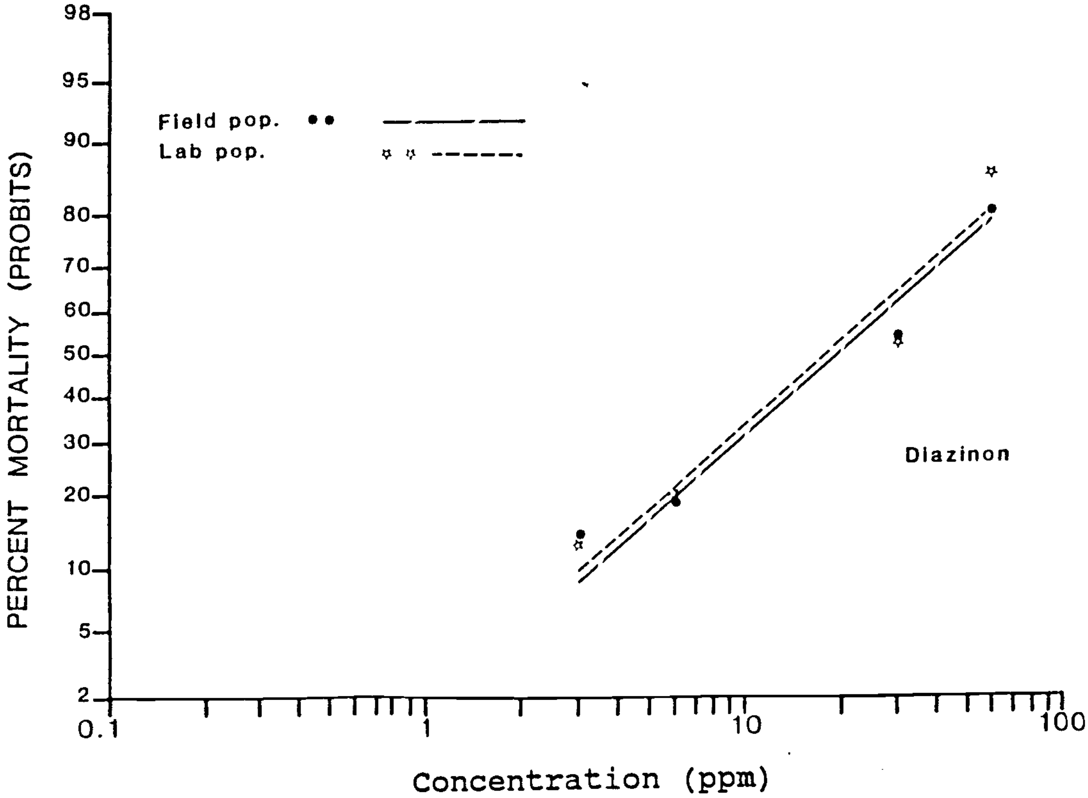


Fig.16. LDP lines of two populations of T. pallidus exposed to Diazinon

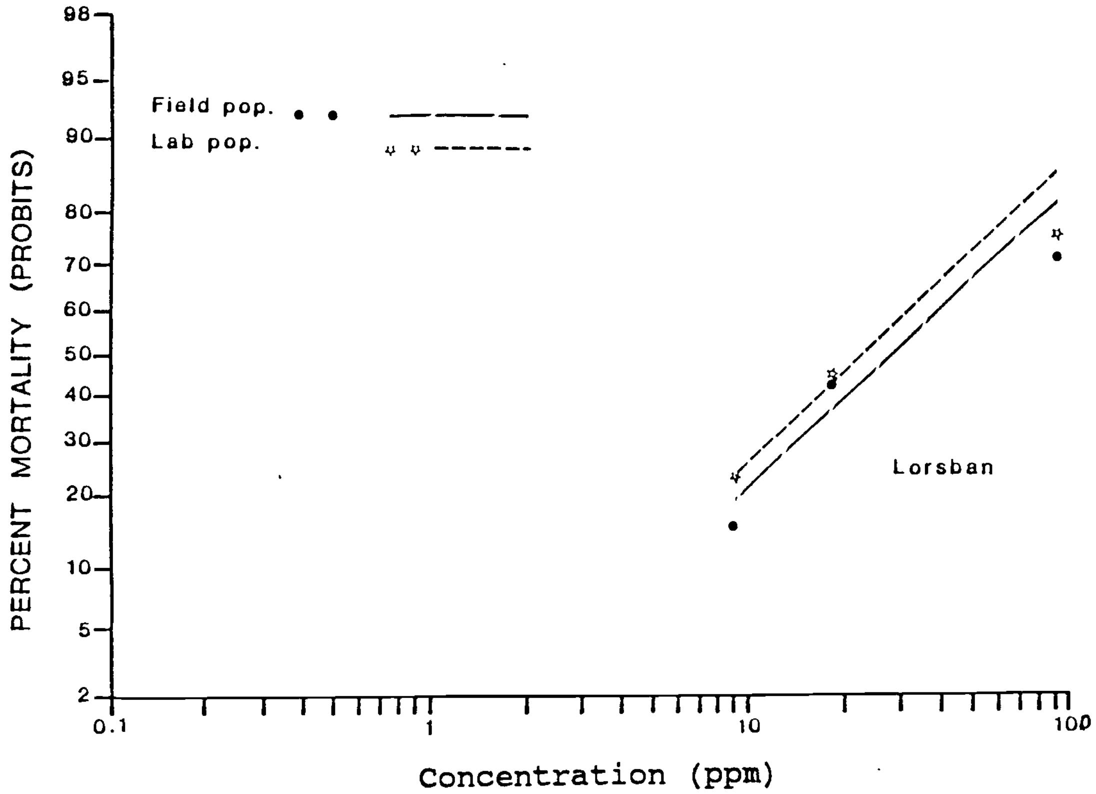


Fig.17. LDP lines of two populations of _T. pallidus_ exposed to Lorsban

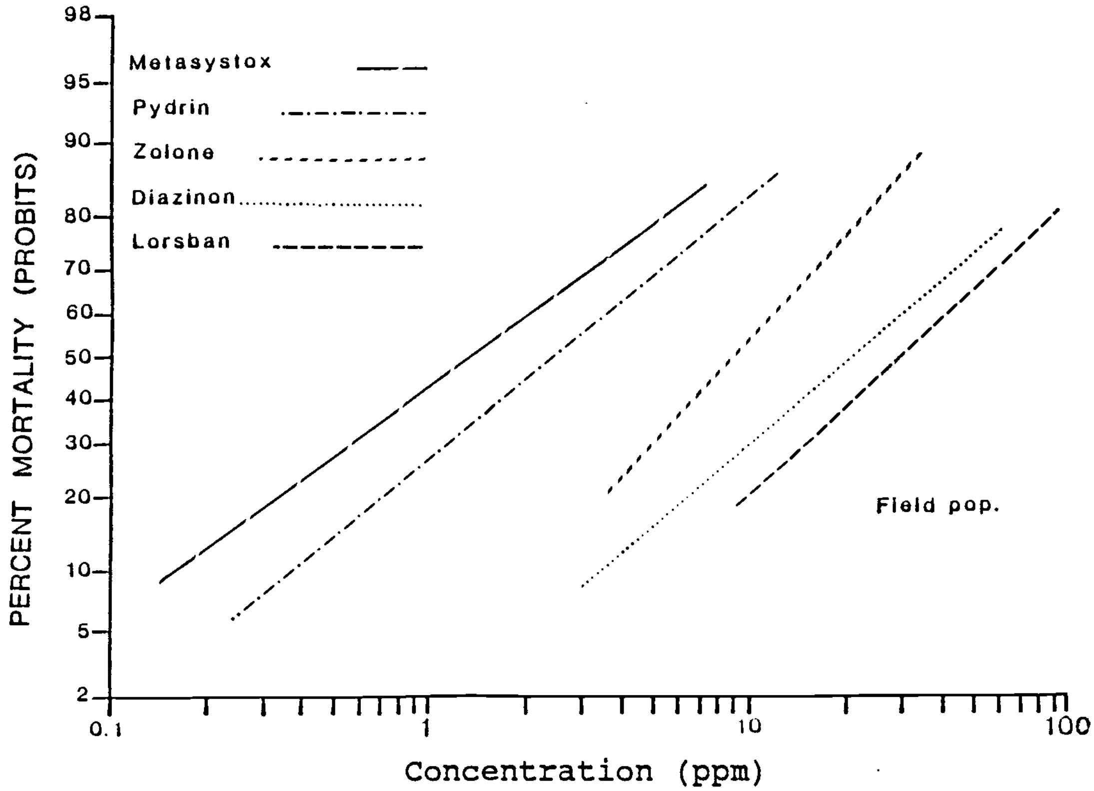


Fig.18. LDP lines of field collected population of *T. pallidus* exposed to five pesticides

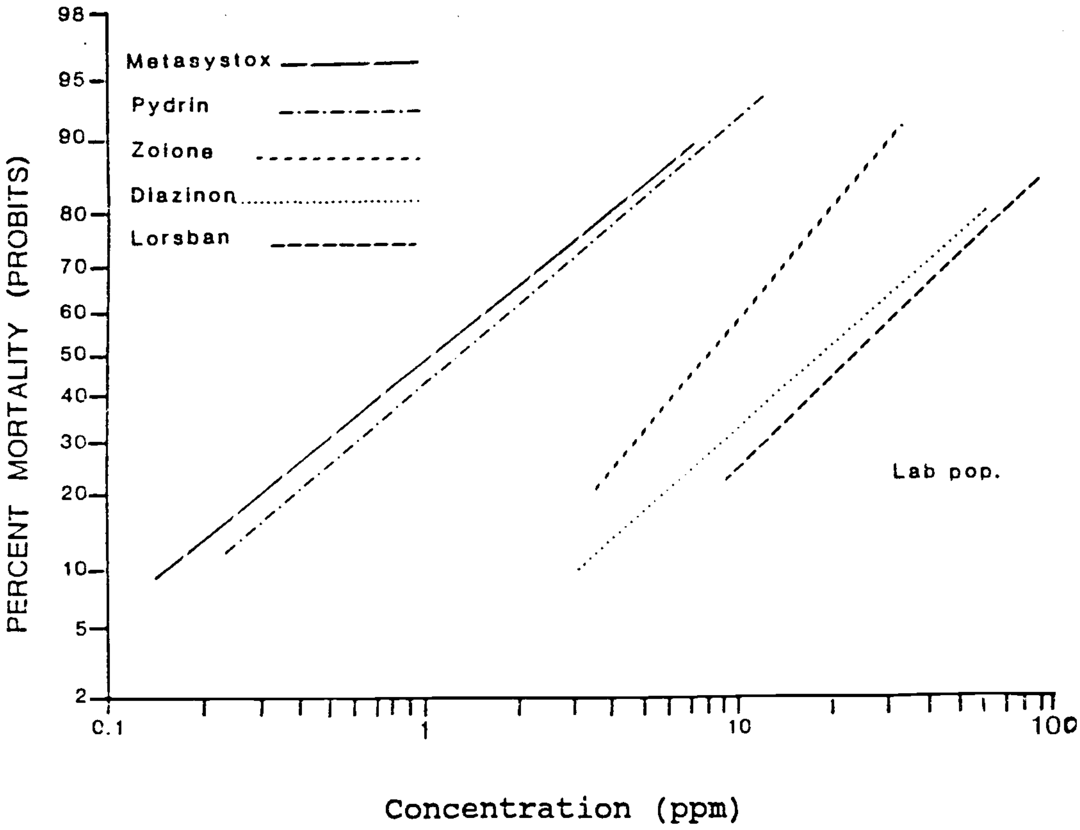


Fig.19. LDP lines of laboratory reared population of *T. pallidus* exposed to five pesticides

The level of resistance appear to be still very low (1.9 fold) in Twedt Orchard (Table II-3 and Figure 5).

The relative tolerance to the insecticides was also compared by estimating RF50 (LC50 of the field population divided by LC50 of the laboratory population) and RF95 (LC95 of the field population divided by LC95 of the laboratory population) values (Table II-2 and Table II-3). The parasitoid adults of the laboratory population were more susceptible to all five test insecticides than the field population. However, the differences were not significant except for Pydrin. The RF values ranged from 1.0 to 1.2 for all four OP and 1.9 for Pydrin, a (SP). A fairly flat LDP line profile 1.53, 1.39, 2.22, 1.71 and 1.75, respectively, for Metasystox, Pydrin, Zolone, Diazinon and Lorsban suggests that the parasitoid is very sensitive to all pesticides, even at very low dosages. T. pallidus adults from the laboratory culture were nearly twice as susceptible to Pydrin as the field population (Table II-2 and Table II-3), indicating the development of some resistance to this insecticide in the latter population.

A similar trend was evident in the field. In Twedt Orchard, a large number of T. pallidus survived during 1987 and 1988 season in spite of application of 2 sprays of Pydrin in both years. It appears that Pydrin resistance is developing in a relatively short period of time (four years), although the resistance levels are

TABLE II-3 COMPARATIVE SUSCEPTIBILITY TO INSECTICIDE OF TWO POPULATIONS OF *TRIOXYS PALLIDUS* (FIELD AND LAB) AT LC95 VALUES

Insecticide	Pop.	No. insects treated	LC95 & 95%(CL) (ug/g)	Slope ± SE	RF95
Metasystox	Field	250	14.19 (7.86-34.62)	1.47 ± 0.23	1.1
	Lab	250	13.30 (7.32-32.41)	1.53 ± 0.25	1.0
Pydrin	Field	250	27.57 (15.54-64.70)	1.84 ± 0.33	1.9
	Lab	250	14.50 (8.47-31.95)	1.39 ± 0.21	1.0
Zolone	Field	250	54.60 (38.27-87.93)	2.03 ± 0.32	1.1
	Lab	250	48.70 (33.95-78.75)	2.22 ± 0.36	1.0
Diazinon	Field	300	206.83 (128.95-403.69)	1.60 ± 0.30	1.1
	Lab	300	185.07 (115.27-360.31)	1.71 ± 0.35	1.0
Lorsban	Field	250	227.59 (119.07-690.81)	1.88 ± 0.31	1.2
	Lab	250	188.03 (99.82-551.94)	1.75 ± 0.31	1.0

Lab: Laboratory, Pop: Population, RF95: LC95 field pop / LC95 lab pop still low. Initially, T. pallidus were more sensitive to Pydrin at Twedt Orchard since the adults released came from the laboratory cultures. The hypothesis of equality was accepted for all comparisons for each chemical except Pydrin where two populations behaved differently to the different concentrations of the same chemical.

A comparison of relative toxicity of each test insecticide showed differences in potency. These differences were noticed against both populations and were perhaps the result of chemical nature of these compounds. These comparative relative potencies are given in (Table II-4). Data in Table II-5 show that when field collected populations were exposed to 1/10 of the field rate of different pesticides, the percent mortality varied from 97 for Metasystox to 81 for Diazinon. Similarly, the data in Table II-5 show that when laboratory T. pallidus adults were subjected to each of the five pesticide at 1/10 of the field rate , their toxicity responses were, respectively, Pydrin> Metasystox> Zolone> Lorsban> Diazinon with percent mortality of 98, 97, 95, 94, 83 for the pesticides tested.

When test insecticides were grouped as most to least toxic based on their percent kill at 1/10 of field rate, the order of toxicity was Metasystox> Pydrin> Zolone> Lorsban> Diazinon for field population, and Pydrin> Metasystox> Zolone> Lorsban> Diazinon for the laboratory

TABLE II-4 RELATIVE TOXICITY OF FIVE DIFFERENT INSECTICIDES TO TWO POPULATIONS OF *TRIOXYS PALLIDUS*

Material	Recommended field rate (ppm)	1/10 of field rate (ppm)	Pop.	Conc. required for 50% mort. (ppm)	Rel. Tox. compared to diazinon
Metasystox	144	14.4	Field	1.13	17.42
			Lab	1.06	16.74
Pydrin	237.5	23.75	Field	2.47	8.25
			Lab	1.30	13.97
Zolone	676	67.6	Field	9.13	2.47
			Lab	8.14	2.50
Diazinon	600	60	Field	20.94	1.00
			Lab	18.73	1.00
Lorsban	1800	180	Field	28.31	0.76
			Lab	23.39	0.87

Pop.: Population, Conc.: Concentration, Mort.: Mortality

Rel. : Relative, Tox.: Toxicity

TABLE II-5 MORTALITY OF TWO POPULATIONS OF TRIOXYS PALLIDUS AT SUB-LETHAL RATES OF FIVE INSECTICIDES

Material	Recommended field rate	% mortality at 0.1 field rate Lab. pop.	Field pop.
Metasystox	0.5 pt	97	97
Pydrin	0.66 pt	98	96
Zolone	1.5 pt	95	95
Diazinon	1.0 lb	83	81
Lorsban	3.0 lb	94	93

Lab: Laboratory, Pop: Population

population.

DISCUSSION

Although all test insecticides were extremely toxic to both laboratory and field populations of T. pallidus at the field rates (used for controlling aphid), there were some differnces in T. pallidus susceptibility at lower rates. The data (Table II-4) show that Metasystox and Pydrin were the most toxic chemicals followed by Zolone, Diazinon and Lorsban. All four organophosphate compounds are regarded as good aphicides while Pydrin is only marginal in controlling aphids. This sort of inherent difference in pesticide toxicities to parasitoids and predators was also reported earlier by Bartlett (1963), Harries and Valcarce (1955), Burke (1959), Stern et al. (1960), and others. These differences may relate to mode of action of these pesticides. In general, however, the differential toxicity is due to the following 3 factors (van den Bosch et al. 1956): a) direct insecticide induced mortality, b) parasitoid feeding on insecticide-affected host, c) starvation of parasitoid due to scarcity of host species. Although, the data presented in this paper deals only with direct-insecticide-induced mortality, the other factors may be important in any field sprayed treatments.

The onset of resistance in the field population of T. pallidus to insecticides is not clearcut. Although, significant levels (nearly twice) of resistance to Pydrin was noticed, no resistance was detected against Metasystox, Zolone, Diazinon or Lorsban. This perhaps relates to the fact that about 6-8 sprays of Pydrin were applied in the field after the release of parasitoid in 1984 and 1985 seasons and only two sprays of Metasystox and none of the other insecticide were applied in the field. Since very limited exposure to OP compounds was present, lack of detectable resistance to these compounds is expected. Hoy and Cave (1988) were able to induce Guthion resistance in a walnut race of T. pallidus by laboratory selection suggesting that genes exist for development of resistance to OP compounds in this parasitoid.

Development of pesticide sprays and resistance profile of other orchards where T. pallidus was released in the Valley may provide a better picture of OP resistance in this insect. In other parasitoids such as Bracon mellitor Say and Trichogramma evanescens Westwood and T. minutum Riley, the development of resistance was very slow or non-existant (Adams and Cross, 1967 and Krukierek et al. 1975). Strawn (1978) showed no significant difference in the response of adults of four populations of Camperiella bifasciata Howard and pupae of six populations of A. mellinus to organophosphate insecticides.

The success of biological control of filbert aphid with T. pallidus is dependent upon the ability of the parasitoid to survive insecticide sprays applied for control of other major pests such as filbertworm and leafroller. This can be achieved either by the development of resistance or avoiding contacts with pesticides. It appears that aestival-hibernal diapause in T. pallidus may help in this regard. As the mummified aphid, containing pupae of T. pallidus, protects them from direct exposure to insecticide, and since most sprays are applied when the parasitoid is in the aestival-hibernating stage, a relatively good survival is expected even in the orchards where OP compounds might be used.

Differential susceptibility of different life stages in parasitoids and predators has been documented by many workers (Bartlett 1964, Newsom and Smith 1945, Campbell and Hutchins 1952, van den Bosch et al. 1956). In general, the egg and larval stages have been seen to be less susceptible than the adult stage (Wilkinson and et al. 1978, Lingren and Ridgway 1967). It has also been recognized that since the internal parasitoid is often protected from direct exposure by proper timing of insecticidal application, these beneficial arthropods can be selectively conserved (Grosch and Valcovic 1967).

The susceptibility of T. pallidus eggs and larvae to insecticide is unknown. Further investigations on the susceptibility of these stages to test insecticides will indeed be helpfull in improving conservation of this species in the filbert orchards of Oregon.

REFERENCES CITED

Adam, C. H. and W. H. Cross. 1967. Insecticide resistance in Bracon mellitor, a parasite of the boll weevil. J. Econ. Entomol. 60: 1016-1020.

AliNiazee, M. T. 1983a. Carbaryl resistance in the filbert aphid (Homoptera: Aphididae). J. Econ. Entomol. 76: 1002-1004.

AliNiazee, M. T. 1983b. Pest status of filbert (hazelnut) insects: a ten year study. Can. Entomol. 115: 1155-1162.

Bartlett, B. R. 1963. The contact toxicity of some pesticide residues to hymenopterous parasites and coccinellid predators. J. Econ. Entomol. 56: 694-698.

Bartlett, B. R. 1964. Integration of chemical and biological control, pp.489-514. In P. DeBack (ed.), Biological control of insect pests and weeds. Reinhold, New York.

Burke, H. R. 1959. Toxicity of several insecticides to two species of beneficial insects on cotton. J. Econ. Entomol. 52: 616-618.

Campbell William, V., and Ross E. Hutchins. 1952. Toxicity of insecticides to some predaceous insects on cotton. J. Econ. Entomol. 45(5): 823-833.

Georghiou, G. P. 1986. The magnitude of the resistance problem, pp. 14-43 in Pesticide resistance. Strategies and tactics for management. National Academy Press, Washington, D. C.

Grosch, D. S., and Valcovic, L. R. 1967. Chlorinated hydrocarbon insecticides are not mutagenic in Bracon hebetor tests. J. Econ. Entomol. 60: 1177-79.

Hoy, M. A., Frances E. Cave. 1988. Guthion-resistant strain of walnut aphid parasite. Calif. Agric. 42:(4) 4-5.

Harris, F. H., and A. C. Valcarce. 1955. Laboratory tests of the effects of insecticides on some beneficial insects. J. Econ. Entomol. 48: 614.

Katundu, J. and M. T. AliNiazee. 1989. Status, Distribution and seasonal variations of filbert aphid. Resistance to selected insecticides in the Willamette Valley, Oregon. J. Econ. Entomol. in press.

Krukierch, T., T. Plenka and J. kot. 1975. Susceptibility of parasitoids of the genus Trichogramma (Hymenoptera, Trichogrammatidae) to Metasystox in relation to their species, host species and ambient temperature. Pol. Ecol. Stud. 1: 183-196.

Lingren, P. D., Ridgway, R. L. 1967. Toxicity of five insecticides to several insect predators. J. Econ. Entomol. 60: 1639-41.

Messing, R. H., and M. T. AliNiazee. 1985. Natural enemies of Myzocallis coryli (Homoptera: Aphididae) in Oregon hazelnut orchards. J. Entomol. Soc. Br.Col. 82: 14-18.

Newsom, L. D., and C. E. Smith. 1949. Destruction of certain predators by application of insecticides to control cotton pests. J. Econ. Entomol. 42: 904.

Russell, R. M., J. L. Robertson and N. E. Savin. 1977. Polo: a new computer program for probit analysis. Bull. Entomol. Soc. Am. 23: 209-213.

Stern, V. M., R. van den Bosch, and H. T. Reynolds. 1960. Effects of Dylox and other insecticides on entomophagous insects attacking field crop pests in California. J. Econ. Entomol. 53: 67-72.

Strawn, A. J. 1978. Differences in response to four organophosphates in the laboratory of strains of Aphytis melinus and Comperiella bifasciata from citrus groves with different pesticide histories. M.S. thesis, Univ. of California, Riverside.

van den Bosch, R., H. T. Reynolds, and E.J. Dietrick. 1956. Toxicity of widely used insecticides to beneficial insects in California cotton and alfalfa fields. J. Econ. Entomol. 49: 359-63.

Wilkinson, J. D., K. D. Biever, C. M. Ignoffo, W. J. Pons, R. K. Morrison, and R. S. Seay. 1978. Evaluation of diflubenzuron formulations on selected insect parasitoids and predators. J. Ga. Entomol. Soc. 13: 227-236.

V. SUMMARY AND CONCLUSION

Trioxys pallidus has been released in thirty orchards of Willamette Valley since 1984. Its establishment was assessed during 1987 and 1988 by sampling the orchards twice in a season. The level of parasitization during 1987 was very encouraging at Twedt Orchard (18.5% and 16% for spring and fall counts) whereas, in other orchards it was below 5%. Although, there were some differences in the rate of parasitization (No. of mummies / No. of aphids + mummies X 100) in fall and spring months, once the establishment had occurred, the parasitoid were found during both seasons. The level of parasitization increased in all of the orchards during 1988, especialy in Twedt Orchard, it went up from 24.9% to 38.4% and aphid populations were reduced dramatically. In brief, it appears that T. pallidus has been established in many orchards of the Willamette Valley, multiplying, dispersing and suppressing the population of filbert aphid.

A total of 5 different dosage concentrations were prepared from a serial solution to test the development of pesticide resistance in this parasitoid. These included 0.1, 0.05, 0.01, 0.005, 0.001 times the recommended field rate for each chemical viz. Metasystox, Pydrin, Zolone, Diazinon and Lorsban. Two populations (one field and one laboratory) were compared by putting adults in treated jars to determine the development of resistance.

The data show that all test insecticides were toxic to T. pallidus and 100% mortality was observed at field rates. The slopes of the regression curve for both population were relatively flat, but variable, suggesting a heterogenous response. The parasitoid adults of the laboratory population were more susceptible to all 5 insecticides than the field population, but differences were insignificant. A fairly flat LDP line profile 1.53, 1.39, 2.22, 1.71 and 1.75 for Metasystox, Pydrin, Zolone, Diazinon and Lorsban, respectively, suggests that the parasitoid is very sensitive to all pesticides even at very low dosages. T. pallidus adults from the laboratory culture were nearly twice as susceptible to Pydrin than a field population from Twedt Orchard indicating the development of some resistance to this insecticide in a relatively short period of time (four years), although the resistance level is still low.

A comparasion of relative toxicity of each test insecticide showed differences in potency against both populations, which perhaps was due to chemical nature of these compounds. The order of toxicity from the most toxic to the least toxic was Metasystox> Pydrin> Zolone> Diazinon> and Lorsban for field population and Pydrin> Metasystox> Zolone> Diazinon> Lorsban for the laboratory population.

The success of biological control of filbert aphid with T. pallidus depends upon a more judiceous and well planned use of insecticides to avoid pesticide toxicity, and releasing of a higher number of parasitoids per release. This will accelerate the rapid establishment of parasitoid and their survival.

VI. BIBLIOGRAPHY

Adam, C. H. and W. H. Cross. 1967. Insecticide resistance in Bracon mellitor a parasite of the boll weevil. J. Econ. Entomol. 60: 1016-1020.

AliNiazee, M. T. 1980. Filbert insect and mite pests. Ag. Exp. Sta. Bull. 643. Oregon State Univ. Corvallis, OR.

AliNiazee, M. T. 1983a. Carbaryl resistance in the filbert aphid (Homoptera: Aphididae). J. Econ. Entomol. 76: 1002-1004.

AliNiazee, M. T. 1983b. Pest status of filbert (hazelnut) insects: a ten year study. Can. Entomol. 115: 1155-1162.

AliNiazee, M. T. 1985. Pests of hazelnuts in North America. A review of their bionomics and ecology. Proc. Intern. Congress of hazelnuts, Avellino, Italy. Sep. 1983, pp. 463-476.

Baron, L. C., and R. Stebbins. 1981. Growing filberts in Oregon. Oregon State Univ. Corvallis, Ext. Bull. 628.

Bartlett, B. R. 1958. Laboratory studies on selective aphicides favoring natural enemies of the spotted alfalfa aphid. J. Econ. Entomol. 51: 374-378.

Bartlett, B. R. 1963. The contact toxicity of some pesticide residues to hymenopterous parasites and coccinellid predators. J. Econ. Entomol. 56: 694-698.

Bartlett, B. R. 1964. Integration of chemical and biological control, pp.489-514. In P. DeBack (ed.), Biological control of insect pests and weeds. Reinhold, New York.

Beirne, B. P. 1975. Biological control attempts by introduction against pest insects in the field in Canada. Can. Entomol. 107: 225-236.

Burke, H. R. 1959. Toxicity of several insecticides to two species of beneficial insects on cotton. J. Econ. Entomol. 52: 616-618.

Calkin, J., M. T. AliNiazee, and G. C. Fisher. 1985. Hazelnut integrated pest management. Proc. Intern. Congress of Hazelnuts. Avellino, Italy. pp. 477-483.

Campbell William, V., and Ross E. Hutchins. 1952. Toxicity of insecticides to some predaceous insects on cotton. J. Econ. Entomol. 45(5): 823-833.

Clausen, C. P. (ed.) 1978. Introduced parasites and predators of arthropod pests and weeds: a world review. USDA-ARS Agric. Handbook 480. 545 pp.

Cohn, J. 1989. Synchronization of Trioxys pallidus with its host, Myzocallis coryli (Goetze) in filbert orchards of Oregon. M.S. thesis, Oregon State Univ. Corvallis. in preparation.

Croft, B. A. and A. W. A. Brown. 1975. Responses of arthropod natural enemies to insecticides. Annu. Rev. Entomol. 20: 285-335.

Croft, B. A. and K. Strickler. 1983. Natural enemy resistance to pesticides: documentation, characterization, theory and application, pp. 669-702. in G. P. Georghiou and T. Saito (eds.), Pest resistance to pesticides. Plenum, New York.

Croft, B. A. (ed.) 1989. Pesticides and Arthropod Biological Control Agents. Wiley-Interscience. in press.

DeBach, P., Bartlett, B. 1964. Methods of colonization, recovery and evaluation. In Biological Control of Insect Pests and Weeds, ed. P. DeBach, 402-26, New York: Reinhold. 844 pp.

El-Haidari, H. 1959. The biology of the filbert aphid, Myzocallis coryli in the Central Willamette Valley. Ph.D. thesis, Oregon State Univ., Corvallis.

Filbert Tree Report. 1985. Oregon crop and livestock reporting service, U.S. Deparment of Agriculture, Portland, Oregon. 4 pp.

Flint, M. L. 1980. Climatic ecotypes in Trioxys complanatus, a parasite of the spotted alfalfa aphid. Environ. Entomol. 9: 501-507.

Force, D. C., and P. S. Messenger. 1964. Duration of development, generation time, and longevity of three Hymenopterous parasites of Therioaphis maculata reared at various constant temperatures. Ann. Entomol. Soc. Am. 57: 405-413.

Force, D. C. and P. S. Messenger. 1965. Fecundity, reproductive rates, and innate capacity for increase of three parasites of Therioaphis maculata (Buckton). Ecology 45: 706-715.

Force, D. C. and P. S. Messenger. 1968. The use of laboratory studies of three hymenopterous parasites to evaluate their field potential. J. Econ. Entomol. 61:

1374-1378.

Frazer, D. C., and R. van den Bosch. 1973. Biological control of the Walnut aphid in California: The interrelationship of the aphid and its parasite. Environ. Entomol. 2: 561-567.

Georghiou, G. P. 1972. The evolution of resistance to pesticides. Annu. Rev. Ecol. Syst. 3: 133-168.

Georghiou, G. P. 1986. The magnitude of the resistance problem, pp. 14-43 in Pesticide resistance. Strategies and tactics for management. National Academy Press, Washington, D. C.

Godwin, H. 1956. The history of the British Flora, a factual basis for phytogeography. Cambridge, the University press. 388 pp.

Grosch, D. S., and Valcovic, L. R. 1967. Chlorinated hydrocarbon insecticides are not mutagenic in Bracon hebetor tests. J. Econ. Entomol. 60: 1177-79.

Hagen, K. S., J. K. Holloway, F. E. Skinner, and G. L. Finney. 1958. Aphid parasites established. Calif. Agric. 12:(3) 15 pp.

Hagen, K. S., and R. van den Bosch. 1968. Impact of pathogens, parasites, and predators of aphids. Ann. Rev. Entomol. 13: 325-384.

Harris, F. H., and A. C. Valcarce. 1955. Laboratory tests of the effects of insecticides on some beneficial insects. J. Econ. Entomol. 48: 614.

Hodek, I. 1966. Ecology of aphidophagous insects. Academia, Prague. 360 pp.

Hoy, M. A., Frances E. Cave. 1988. Guthion-resistant strain of walnut aphid parasite. Calif. Agric. 42:(4) 4-5.

Huffaker, C. B., M. van de vrie and J. A. McMurtry. 1969. The ecology of Tetranychid mites and their natural control. Annu. Rev. Entomol. 14: 125-174.

Huffaker, C. B. (ed.). 1971. Biological control. Plenum-Rostta. 511 pp.

Huffaker, C. B., and P. S. Messenger (eds.). 1976. Theory and practice of biological control. Academic press. 788 pp.

Hsieh, C. Y. 1984. Effects of insecticides on Diaeretiella rapae (M'Intosh) with emphasis on bioassay techniques for aphid parasitoids. Ph,D. dissertion, Univ. of California, Berkeley.

Kasapligil, B. 1963. A contribution to the histotaxonomy of Corylus (Betulaceae). Adonsonia 4: 43-90.

Katundu, J., and M. T. AliNiazee. 1989. Status, Distribution and Seasonal Variations of filbert aphid. Resistance to selected insecticides in the Willamette Valley, Oregon. J. Econ. Entomol. In press.

Krukierch, T., T. Plenka and J. kot. 1975. Susceptibility of parasitoids of the genus Trichogramma (Hymenoptera, Trichogrammatidae) to Metasystox in relation to their species, host species and ambient temperature. Pol. Ecol. Stud. 1: 183-196.

Lagerstedt, H. B. 1975. Filberts, pp 456-489 in J. Janick and J. N. Moore (eds.). Advances in Fruit Breeding. Purdue University Press, West Lafayette.

Lingren, P. D., Ridgway, R. L. 1967. Toxicity of five insecticides to several insect predators. J. Econ. Entomol. 60: 1639-41.

Mackauer, M., and P. Stary. 1967. Hym. Ichneumonoidea. World Aphidiidae. In: V. Delucchi and G. Remaudiere (eds.), Index of entomophagous insects. Paris, 195 pp.

Messing, R. H. 1982. Biology of the predator complex of the filbert aphid, Myzocallis coryli (Goetze), in western Oregon. M.S. thesis, Oregon State Univ. Corvallis.

Messing, R. H. 1985. Parasites of the filbert aphid imported from Europe. Proc. Oreg. Wash. and B. C. Nut Growers Soc. 70: 96-100.

Messing, R. H., and M. T. AliNiazee. 1985. Natural enemies of Myzocallis coryli (Homoptera: Aphididae) in Oregon hazelnut orchards. J. Entomol. Soc. B.C. 82: 14-18.

Messing, R. H. 1986. Classical Biological Control of the filbert aphid, Myzocallis coryli (Goetze) (Homoptera: Aphididae) in Western Oregon. Ph.D. thesis, Oregon State Univ., Corvallis.

Messing, R. H. and M. T. AliNiazee. 1989. Importation and establishment of Trioxys pallidus (Hym.: Aphidiidae) on filbert aphid, Myzocallis coryli (Hom.: Aphididae) in western Oregon, U.S.A. Entomophaga, in press.

Newsom, L. D. 1974. Predator insecticide relationships. Entomophaga Mem. Ser. 7: 13-23.

Newsom, L. D., and C. E. Smith. 1949. Destruction of certain predators by application of insecticides to control cotton pests. J. Econ. Entomol. 42: 904.

Nowierski, R. M. 1979. The field ecology of the Walnut aphid Chromaphis juglandicola (Homoptera: Aphididae) and its introduced parasite, Trioxys pallidus (Hymenoptera: Aphidiidae)--- a qualitative and quantitative assessment of population regulation. Ph.D. Thesis, Univ. of Cal. Berkely. 231 pp.

Olkowski, W., H. Olkowski, R. van den Bosch and R. Hom. 1976. Ecosystem management: a framework for urban pest control. Bioscience. 26: 384-389.

Olkowski, W., H. Olkowski, R. Van den Bosch. 1982. Linden aphid parasite establishment. Environ. Entomol. 11: 1023-1025.

Pacific Northwest Insect Control Handbook, 1988. Extension services of Oregon State Univ., Washington State Univ., and the Univ. of Idaho.

Painter, J. H., and S. C. Jones. 1960. Effect of aphid control on quality and yield of filberts in 1960. Proc. Oregon and Washington Nut Growers Soc. 46: 23-24.

Pimentel, D. 1961. An ecological approach to the insecticide problem. J. Econ. Entomol. 54: 108-114

Powell, W., G. J. Dean and R. Bardner. 1985. Effects of pirimicarb, dimethoate and benomyl on natural enemies of cereal aphids in winter wheat. Ann. Appl. Biol. 106: 235-242.

Purcell, M., Granett, J. 1985. Toxicity of benzoylphenyl ureas and thuringiensin to Trioxys pallidus (Hymenoptera:Braconidae) and the walnut aphid (Homoptera:Aphididae). J. Econ. Entomol. 78: 1133-1137.

Richard, W. C. 1968. A synopsis of the world fauna of Myzocallis (Homoptera: Aphididae). Mem. Entomol. Soc. Can. 68.

Ripper, W. E. 1956. Effects of pesticides on balance of arthropod populations. Annu. Rev. Entomol. 1: 403-38.

Russell, R. M., J. L. Robertson and N. E. Savin. 1977. Polo: a new computer program for probit analysis. Bull. Entomol. Soc. Am. 23: 209-213.

Schlinger, E. I., and J. C. Hall. 1959. A synopsis of the biologies of three imported parasites of the spotted alfalfa aphid. J. Econ. Entomol. 52: 154-157.

Schlinger, E. I., and J. C. Hall. 1961. The biology, behavior and morphology of Trioxys utilis, an internal parasite of the spotted alfalfa aphid, Therioaphis maculata (Hymenoptera:Braconidae, Aphidiinae). Ann. Entomol. Soc. Am. 54: 34-45.

Schlinger, E. I., K. S. Hagen, and R. Van den Bosch. 1960. Imported French parasite of walnut aphid established in California. Calif. Agric. 14: 3-4.

Schoonees, J. and J. H. Giliomee. 1982. The toxicity of methidathion to parasitoids of red scale, Aonidiella aurantii (Hemiptera: Diaspididae). J. Entomol. Soc. South Afr. 45: 261-173.

Shorey, H. H. 1963. Differential toxicity of insecticides to the cabbage aphid and two associated entomophagous insect species. J. Econ. Entomol. 56: 844-847.

Sluss, R. R. 1967. Population dynamics of the walnut aphid, Chromaphis juglandicola (Kalt.) in northern California. Ecology 48: 41-58.

Smith, R. F., and K. S. Hagen. 1959. Integrated control programs in the future of biological control. J. Econ. Entomol. 55: 5-11.

Stary, P. 1970. Biology of aphid parasites with respect to Integrated control. Series Entomologica 6: 643 pp. Dr. W. Junk, The Hague.

Stern, V. M., R. van den Bosch, and H. T. Reynolds. 1960. Effects of Dylox and other insecticides on entomophagous insects attacking field crop pests in California. J. Econ. Entomol. 53: 67-72.

Strawn, A. J. 1978. Differences in response to four organophosphates in the laboratory of strains of Aphytis melinus and Comperiella bifasciata from citrus groves with different pesticide histories. M.S. thesis, Univ. of California, Riverside.

van den Bosch, R., H. T. Reynolds, and E.J. Dietrick. 1956. Toxicity of widely used insecticides to beneficial insects in California cotton and alfalfa fields. J. Econ. Entomol. 49: 359-63.

van den Bosch, R., Stern, V. M. 1962. The integration of chemical and biological control of arthropod pests. Annu. Rev. Entomol. 7: 367-386.

van den Bosch, R., C. A. Ferris, L. K. Stromberg, L. A. Falcon, T. F. Leigh, R. E. Stinner and L. K. Etzel.

1968. A comparison of season-long cotton-pest control program in California during 1966. J. Econ. Entomol. 61: 633-642.

van den Bosch, R., B. D. Frazer, C. S. Davis, P. S. Messenger, and R. Hom. 1970. *Trioxys pallidus*, an effective new walnut aphid parasite from Iran. Calif. Agric. 24: 8-10

van den Bosch, R., E. I. Schlinger, E. J. Dietrich, K. S. Hagen And J. K. Holloway. 1958. The colonization and establishment of imported parasites of the spotted alfalfa aphid in California. J. Econ. Entomol. 52: 136-141.

van den Bosch, R., E. I. Schlinger, and K. S. Hagen. 1962. Initial field observations in California on *Trioxys pallidus*, (Holiday),a recently introduced parasite of Walnut aphid. J. Econ. Entomol. 55: 857-862.

van den Bosch, R., C. A. Ferris, L. K. Stromberg, L. A. Falcon, T. F. Leigh, R. E. Stinner and L. K. Etzel. 1968. A comparison of season-long cotton-pest control program in California during 1966. J. Econ. Entomol. 61: 633-642.

van den Bosch, R., R. Hom, P. Matteson, B. D. Frazer, P. S. Messenger, and C. S. Davis. 1979. Biological control of the walnut aphid in California: impact of the parasite *Trioxys pallidus*. Hilgardia. 47: 1-13.

Ware, George W. 1980. Effects of pesticides on nontarget organisms. Residue Reviews, Vol. 76, 1980.

Wilkinson, J. D., K. D. Biever, C. M. Ignoffo, W. J. Pons, R. K. Morrison, and R. S. Seay. 1978. Evaluation of diflubenzuron formulations on selected insect parasitoids and predators. J. Ga. Entomol. Soc. 13: 227-236.

APPENDIX

Table A-1 LIST OF *TRIOXYS PALLIDUS* RELEASES

Grower's name and site	Released by	Date of release	No. & stage released	Mummies found
Twedt Homer (757-7814) Garden Ave. Rt. 20 Corvallis	Messing	6,8/84 4,5,6,7/85	150A 6800A	Yes
Calef Jerry (344-6185) Coberg Eugene	Messing	6/85	300A	Yes
Simonson 31110 Bellfountain Rd.	Messing	7/85	300A	Yes
Gray (928-0081) Couser Rd. Albany	Messing	5,6/85	400A	Yes
David Buchanan (753-8754) 26335 Greenberg Rd. Bellfountain	Messing	4,6/85	6300A	Yes
Knittel Martin (754-8348) Kiger Island	Messing	4,5/85	2400A	Yes

Table A-1 (Continued)

Lemert Milo Lucry Rd. Junction City	Messing	9,10/84	2350A	Yes
Don duncan (244-4255) 9134 W 40, Portland	Cohn	5/87	70A 100M	Yes
Newton Jorgensen (928-2111) Rt. 2 Box 109C albany	Cohn	5,7/87	185A 25M	Yes
Abraham Independence Highway, Albany	Messing	7/84	15A	No
Dick Bryant Rt 219, Newberg	Messing	4/85	200A	No
Adelman Jim (393-6185) Brooks Salem	Messing	5/85	300A	No
Malone Rick (835-8861) 99W (N) Amity	Messing	8,9/84	400A	No
Duane Bush 200 S Fern Ridge Dam Eugene	Messing	9/84	1850A	No
Richard Gingerich (651-2440) 10882 S Heinz Rd. OR 97013	Cohn	5,7/87	140A 75M	No
Peter MacDonald (625-7437) 15700 SW Wilsonville Rd. Wilsonville	Cohn	4,7,9/87	185A 360M	No

Table A-1 (Continued)

Dennis Pierce (538-2363,9144) 30690 Fernwood Rd. Newberg	Cohn	4,6/87	170A 360M	No
Huffman (as above) Newberg	Cohn	4,6,7,9/87	435A 260M	No
Bestwick (as above) Newberg	Cohn	4,6,9/87	245A 160M	No
Pierce (as above) Newberg	Cohn	4,5,6,9/87	355A 160M	No
Skene Pierce (as above) Dundee	Cohn	4,5/87	95A 100M	No
Ben Mitchell III (538-2401) Flying Feather Orchards, 21800 NE North Valley Rd. Newberg, OR 97123	Cohn	5,7,9/87	235A 210M	No
Paul Nofziger Dever Conner	Cohn	5,6/87	250A 100M	No
Judy Cohn (25447 Bruce Rd. Monroe OR 97456	Cohn	7/87	80A	Yes
Winnie Wennerstrom (472-4841) McMinnvill	Cohn	-/86	600M	No
Mark Schrapel (662-3972) Yamhill	Cohn	-/86	6A	No

Table A-1 (Continued)

Jay Gratt Woodburn	Cohn	-/86	60A	No
Phil Downing (359-4560) Box 101 Sandstorm Rd. Gaston OR	Saeed	7/88	150A	No
Don Blake (585-5428) 2985 River Bend Road NW Salem, OR	Saeed	10/88 5/89	100A 60A	Yes
Paul Smith 4560 Tract Rd. Monroe, Oregon	Cohn	7/87	200A	No

A: adult, M: mummies, Messing: Russel Messing,

Cohn: Judy Cohn, Saeed: Mohammd Saeed