INTRODUCTION OF TWO EXOTIC COCCINELLIDS TO OKLAHOMA: INOCULATIVE RELEASES OF *MENOCHILUS SEXMACULATUS* (F.) AND *COCCINELLA SEPTEMPUNCTATA* L.

By

BOBBY OLIVER CARTWRIGHT

Bachelor of Science in Agriculture

Oklahoma State University

Stillwater, Oklahoma

1978

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
July, 1979

INTRODUCTION OF TWO EXOTIC COCCINELLIDS TO OKLAHOMA: INOCULATIVE RELEASES OF MENOCHILUS SEXMACULATUS (F.) AND COCCINELLA SEPTEMPUNCTATA L.

Thesis Approved:

Thesis Adviser

Don C Peters

John K. Sauer

Robert D Morrison

Norman N. Durham

Dean of the Graduate College

ACKNOWLEDGEMENTS

The importation, release and establishment of beneficial insects is the basis of classical biological control. The science of biological control is very much dependent on this approach to insect control. I feel most fortunate to have been exposed to the same type of research as that conducted by the all time great scientists of biological control.

It is to my major professor and friend, Dr. Raymond Eikenbary, that I owe much gratitude. He was responsible for my early exposure to entomological research and professional writing. Dr. Eikenbary provided greatly needed encouragement, often at crucial times. For his role above and beyond that of adviser, I am deeply indebted.

My sincere thanks are extended to the staff of the Beneficial Insects Research Laboratory in Newark, Delaware, especially Mr. George Angalet, Mr. Joe Tropp and Ms. Alissa Eggert for providing the lady beetles for release.

I am also grateful to the Oklahoma Agricultural Experiment Station for financial support for much of this work.

I would like to thank Dr. Robert Burton, Dr. Robert Morrison and Dr. John Sauer who were considerate in providing timely advise as members of my committee, as well as valuable manuscript critiques. Also, Dr. Jakie Hair and Dr. Don Peters have very thoughtfully given me much encouragement and helpful advise.

Appreciation is also extended to the extension entomologists of

the Department of Entomology, especially Dr. Ken Pinkston, Don Arnold, Bob Hill and Terry Pitts for their assistance in finding fields for releases.

Very importantly, I want to thank the staff of our laboratory for various assistance throughout this study, especially, Ms. Tamara Farris, Ms. Mary Leonard, Mr. Russell Campbell, Mr. Bryan Henderson, Mr. Jamie Yanes and Mr. Steven Jiracek. Also, thanks goes to Ms. Anne Hunt for typing this manuscript. With very special thanks, I acknowledge the support and encouragement provided by my entire family, especially my wife, Delores, my daughter, Valerie, and my parents Delores particularly, has given a great amount during this time while receiving very little in return. To her goes my greatest appreciation.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Since the historic success of the vedalia beetle, Rodalia cardinalis Mulsant, released in California against Icerya purchasi Mask. in 1888, introduced coccinellids have been the thrust of numerous attempts at biological control. DeBach (1964) lists releases of coccinellids made in the U.S. since the late 1800's, each having varying degrees of success. Introductions of exotic coccinellids to the U.S. include Chilocorus bipustulatus L. in California olive groves to control Parlatoria oleae (Colvee) (Huffaker and Doutt, 1965), Crytolaemus montouzieri (Mulsant) from Australia in 1891-2, Telsimia nitida (Chapin) from Guam in 1936, and Chilocorus nigritus (F.) from India in 1938.

While the bulk of these introductions of coccinellids in the U.S. have been directed twoard scale insects, introductions of lady beetles against aphid pests have also occurred. Laing and Hamai (1976) list the successful introduction of Coleophora inaequalis (F.) to the U.S. from Australia in 1894 for control of the sugar cane aphid, Longiunguis sacchari (Zentner), being possibly the earliest such introduction.

Propylea quatuordecimpunctata (L.) from France and M. sexmaculatus (F.) from Pakistan were released in small numbers in New Jersey and Delaware in 1971 but were never recovered. Adonia variegata (Goeze)

from India was released in New Jersey and Delaware, but again none were found the year after release (Angalet, unpublished data).

In Oklahoma, efforts have been made to introduce exotic lady beetles in an effort to supplement the entomophagous fauna. Both P. quatuordecimpunctata and A. variegata have been released here as a predator of the greenbug, Schizaphis graminum (Rondani), with establishment being unsuccessful.

As part of this continuing effort to import aphidivorous coccinellids to Oklahoma, two species were chosen to utilize against aphid pests, namely, Menochilus sexmaculatus (F.) and Coccinella septempunctata L.

Menochilus sexmaculatus (F.) is an aphidophagous coccinellid common in India, Pakistan and the surrounding region (Phillipines, Borneo, Sumatra, Java, China, New Guinea, Japan and Ceylon,) (Azim and Ahmed 1966). The biology and life history of M. sexmaculatus has been studied in relation to predation on aphids by Modawal (1941), Bagal and Trehan (1945) and later by Azim and Ahmed (1966) and by Rajamohan and Jayaraj (1974). In addition, the contribution of M. sexmaculatus as a predator of non-aphid prey is reported by Patel (1968), Jotwani and Verma (1969), Puttarudriah and Basavanna (1953) and Butani (1958). The polymorphic coloration of M. sexmaculatus is discussed by Subramanayam (1923) and Kapur (1939). Parker et al. (1976), Gupta and Kushwakea (1970) and Satpathy et al. (1968) determined some of the effects of certain insecticides of M. sexmaculatus. The influence of toxic plants on M. sexmaculatus through aphid predation was studied by Chelliah (1971), while Gwande (1966) determined some of the effects of temperature on this predator.

Prior to this study, only one confirmed attempt to establish M. sexmaculatus in the United States had been made. Large numbers of these coccinellids were shipped from India to Brownsville, Texas, during the 1950's. However, since these beetles came from a warm region, they were unable to survive even the relatively mild winters of Brownsville, Texas (pers. comm. G. W. Angalet). An apparently more hardy strain of M. sexmaculatus that was found active after November snowfall was collected by Dr. M. A. Ghani in northern Pakistan. This strain of M. sexmaculatus was shipped to the United States and processed by the quarantine facility at the Beneficial Insects Research Laboratory (USDA-SEA) located at Newark, Delaware before being forwarded to Oklahoma for release against the greenbug, Schizaphis graminum (Rondani).

Only 213 adult M. sexmaculatus were received in April 1975, thus, an effort ensued to mass rear larger numbers of the beetles for release.

Though establishment of this predator was the primary goal in this study, the dispersal behavior of M. sexmaculatus was of utmost interest. The effectiveness of an introduced predator is often judged by the period of time the predator will remain in a given area. DeBach and Bartlett (1964) discuss the adaptive advantage of slow dispersing species which allows adequate mating of progeny of the released beetles and also prevents dilution of small initial populations.

The dispersal behavior of insects from a single point has been the subject of much literature including studies by Wolfenbarger (1946), Macleod and Donnelly (1963), Doane (1963), Johnson et al. (1974), Waddill and Shepard (1975), and Maier (1979). Only a few studies have reported on the movement of coccinellids in the field. Ewert and Chiang (1966) compared dispersal characteristics of 3 coccinellid species in

corn fields. Rapid dispersal of Hippodamia convergens (Guerin-Meneville) that were collected in the Sierra Nevada Mountains is reported by Davidson (1924). Similar studies on this species by Fenton and Dahms (1951), Kieckhefer and Olson (1974) and Starks et al. (1975) again showed rapid dispersal with a low recovery rate. Therefore, the objective in this study was to determine the degree to which M. sexmaculatus exhibits this nomadic behavior. From this, the feasibility of liberating large numbers of these beetles could be determined.

The other lady beetle species chosen for introduction to Oklahoma in this study, Coccinella septempunctata L., is an aphidivorous coccinellid native to much of Asia, Europe, and North Africa. It is perhaps the best understood old world species; documentation of its predation abounds. Hodek (1973) extensively reviewed a variety of work exemplifying the aphidophagy of C. septempunctata. Hodek has also been a primary contributor to the knowledge of dormancy, food relations, general biology, and ecology of this species.

Hagen (1963) also reviewed much of the early biological and ecological research pertaining to this species and provides a substantial summary of its voltinism, dormancy and aggregation behavior. Hamalainen and co-workers (1975) described the fecundity and larval voracity; storage of adults was reported by Hamalainen (1977a), and laboratory rearing by Hamalainen (1976). The insect's effectiveness against aphids of sweet peppers, chrysanthemums, and roses was discussed by Hamalainen (1977b). Ali and Azam (1977) attempted to curb dispersal of this beetle by starvation, spraying of sugar solution, and immobilization of the wings. Sundby (1968) discussed the effects of host aphids and artificial foods as well as the importance of hibernacula. Other biology and

feeding behavior studies include Blackman (1965, 1967), Gurney and Hussey (1970), Aziz et al. (1969), Murdoch and Marks (1973), Radke et al. (1977), and Bagal and Trehan (1945).

Clayhills and Markkula (1974) found C. septempunctata to be the dominant coccinellid on cereals, potato, clovers, alfalfa, apple trees and berry bushes in Finland comprising 48 - 98% of the total number of lady beetles. With such documentation of its worth as an aphid predator, it is no surprise that a number of attempts to establish C. septempunctata in the United States have occurred in the past several decades.

Introductions of C. septempunctata to the United States were begun with shipments from India to southern California in 1956 (Angalet unpublished data). Shipments were followed by introductions from Europe to the Beneficial Insects Research Laboratory, Newark, Delaware, during the years 1958 to 1973. Shands and co-workers (1972a, b) documented releases of C. septempunctata for aphid control in Maine, however, no evidence of establishment was found. Somewhat later, Angalet and Jacques (1975) reported the establishment of this predator on the east coast of the United States. Large numbers of beetles were found overwintering in aggregations centered in and around the Hackensack Meadowlands, Bergen County, of eastern New Jersey. Following this discovery, subcolonization efforts were initiated (1975) in Oklahoma. Most beetles that were released in Oklahoma were collected at the New Jersey location by G. W. Angalet and the staff of the Beneficial Insects Research Laboratory (BIRL) in Newark, Delaware. Subcolonization of established beneficials could be attempted without the completion of quarantine requirements. Therefore, establishment attempts of C. septempunctata were not dependent on mass rearing programs as were quarantined beneficials, thus,

possible genetic degradation caused by laboratory breeding was avoided (Mackauer 1976). It was our objective to take advantage of subcolonization and release large numbers of adult C. septempunctata in Oklahoma. The release and recovery of C. septempunctata are reported in this paper.

CHAPTER II

METHODS AND MATERIALS

Release and Dispersal of *Menochilus sexmaculatus* (F.)

Adult *M. sexmaculatus* were reared in the laboratory under a 15:9 (L.D) photoperiod at 27 ± 2.5 C and 45-65% RH. The cannibalistic larvae were isolated into 29.6 ml plastic cups and fed an excess of greenbug, *S. graminum*. Upon emergence, adults were transferred to 240 ml ventilated ice cream cartons and held at 15.5 C under a 12 h photoperiod until release.

An overriding objective in releasing *M. sexmaculatus* was their colonization and subsequent establishment. Therefore, in assessing their dispersal, the method chosen was such that colonization would not be adversely affected (e.g. sticky traps, pitfall traps, etc.).

A marking procedure was not necessary in studying the dispersal of *M. sexmaculatus* since the release beetle could be readily distinguished from any of the native coccinellids.

1975 Field Releases

The release of 848 adult *M. sexmaculatus* was made in a mixed variety sorghum field located on the Oklahoma Agriculture Experiment Station, nine miles south of Stillwater, Oklahoma, on 29 July 1975. To assess beetle dispersal, 9.2 m^2 plots arranged around the release

point at distances of 3.0 m, 7.6 m, 15.2 m, (Figure 1). During the day of release beetles were counted in the sample plots hourly for the first 8 h post release. Thereafter, samples were taken daily for two weeks and then weekly for six weeks. Aphid populations were estimated by making random counts on 50 plants for each sampling.

1976 Field Release

Due to low beetle recovery in 1975 the number of sample plots were increased, resulting in a proportionally equal area sampled at each distance from the release point. These changes in plot arrangement are similar to the changes made by Doane (1963) during a two-year period.

Dispersal of the beetles released in 1976 was assessed by counting the number of released beetles in 3.3 m^2 plots equally spaced around concentric circles at distances of 6.1 m, 12.2 m, and 24.4 m from the release point (Figure 2). A 3.3 m^2 plot surrounding the release point was also sampled. The sampling regime followed was: three times on the day of release, daily for one week, twice weekly for two weeks, and once weekly for the remaining two weeks.

In the 1976 study, three releases of M. sexmaculatus were made. Two releases were made simultaneously at two sorghum fields (536 in Field One and 500 in Field Two) located north of Cushing, Oklahoma, in Payne County on 26 June 1976. Each field was ca. 8 ha and ca. the same age. The third release of 1014 beetles was made 3 August 1976 in a sorghum field located on the Oklahoma Agriculture Experiment Station, nine miles south of Stillwater, Oklahoma, in Payne County. Here, the field was ca. 2 ha and surrounded by a variety of other crops (cotton, guar, vetch, apples, peaches, corn, and others). The release point for all

Figure 1. Arrangement of Sample Plots in Dispersal Study of Menochilus sexmaculatus (F.), 1975.

ARRANGEMENT OF SAMPLE PLOTS
1975

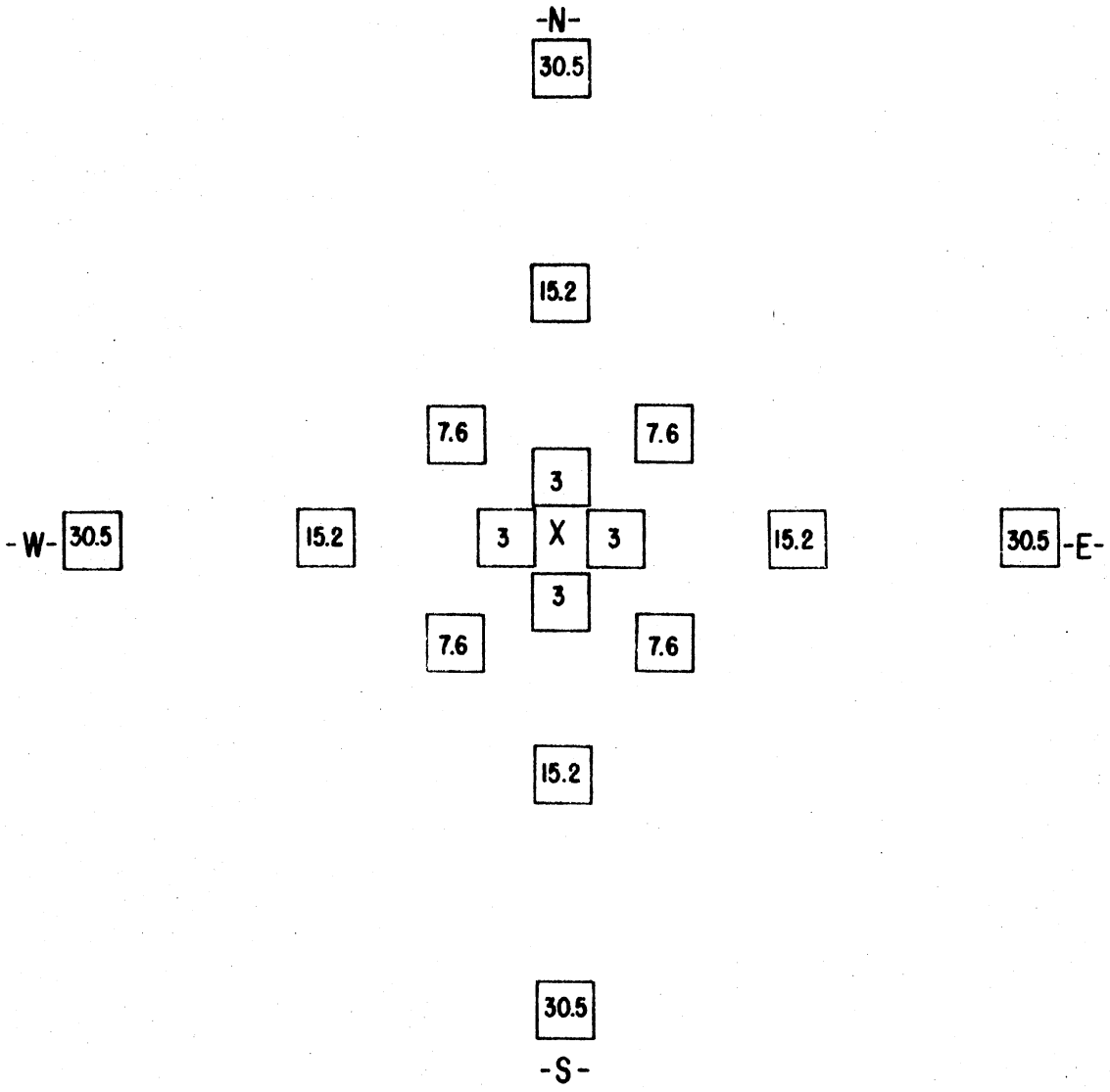
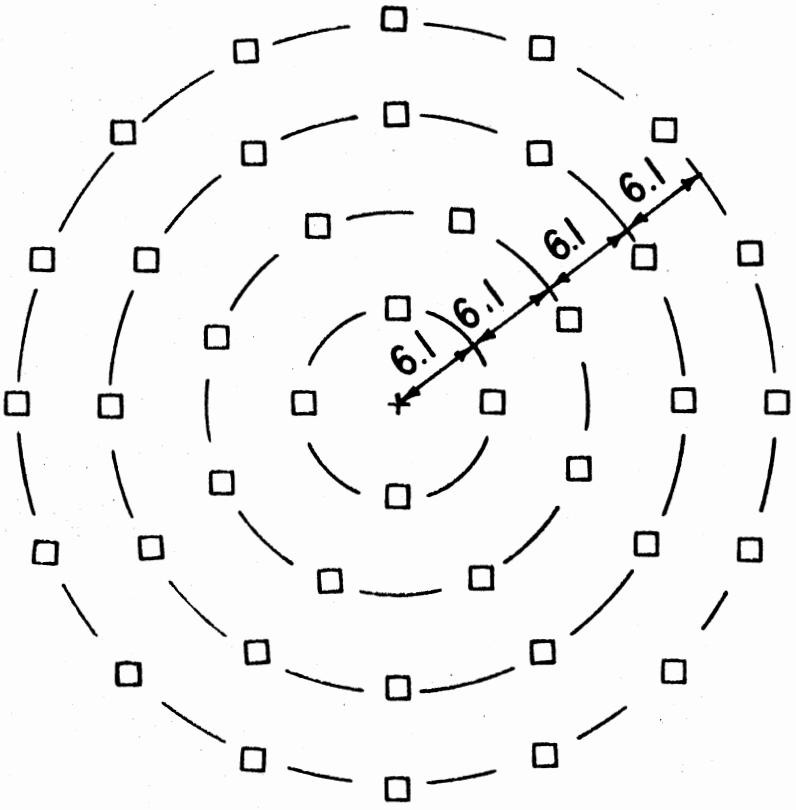


Figure 2. Arrangement of Sample Plots in Dispersal Study of *Menochilus sexmaculatus* (F.), 1976.

1976

ARRANGEMENT OF SAMPLE PLOTS



releases was the middle of the field.

Flight observations were made in Fields one and three during the 1976 study. Observations were made continually during a 6 h period following release by recording the number of beetles flying in each direction from the release point. Flight observations were recorded for fifty beetles in Field One and sixty-five beetles in Field Three.

Introduction of *Coccinella septempunctata* L.

Releases

Releases of *C. septempunctata* L. were made in two ways depending on the time of year. First, adult *C. septempunctata* (presumed by their inactivity to be in diapause) collected during the fall in the Meadowlands of New Jersey were released in "overwintering cages" of two types: 1) a large wooden frame cage (2.5m X 1.5m X 1.5m) covered with screen wire and a plywood top, and 2) several small animal cages (28 cm X 28 cm with 1.2 cm screen wire mesh and a solid metal top). A variety of materials was placed in the cages in an attempt to provide a suitable microhabitat. Materials that were utilized for beetle overwintering inside cages included: pine clippings; artificial scotch pine; dried mullein, (*Verbascum thapsus* L. leaves); excelsior; styrofoam packing; and wood chips. In the spring, cages were opened to release beetles to adjacent vegetation infested with aphids. The smaller cages, buried in hedgerows, allowed emigration of the beetles to surrounding leaf litter during warmer temperatures (above $20^{o}C$). The release habitats were intentionally varied with alfalfa being the most frequent release crop. A second mode of release was to liberate spring and summer col-

lected beetles directly into the habitat chosen from releasing beetles. Most releases were divided into groups in each field rather than being placed in one point depending on the number of beetles available for release and on the size of the field.

Recoveries

Wherever possible, a systematic recovery system was attempted. This included dividing fields (less than 10 ha) into five sections according to direction. Twenty standardized sweeps with 38 cm diameter net were taken in each section (NE, NW, SW, SW, and Central). Additional sweeps were taken proportionally for fields larger than 10 ha. "Walking counts" (visual counts/given linear distance, usually ca 35 m) were made in habitats where sweeps could not be made. In addition, general visual searches were made in areas where C. septempunctata might be found.

When recoveries occurred, host plant and host aphid collections were made. Unknown host plants were determined by Dr. Ronald Tyrl, Department of Botany, Oklahoma State University, Stillwater, Oklahoma. Aphid determinations were made by Dr. Manya Stoetzel, USDA-SEA-IIBIII, Beltsville, Maryland.

CHAPTER III

RESULTS AND DISCUSSION

Release and Dispersal of *Menochilus sexmaculatus* (F.)

1975 Study

The aphid population at the time of release was ca. 1500 per plant. During the first 8 h post release, dispersal of *M. sexmaculatus* was relatively gradual. The majority of the released beetles walked to adjacent plants. Feeding, mating, and oviposition were observed during the day of release, with 28% of the 848 released beetles remaining within 1.5 m of the release point. Figure 3 summarizes the total number of beetles recovered daily through 14 days post release. No beetles were observed at the 15.2 m or 30.4 m sample plots. The beetles recovered 9, 12, 13 and 14 days post release are of the F_1 generation as evidenced by the presence of immature forms. No beetles were recovered after 14 days. The dispersal of the second generation was more rapid than that of the adults originally released. The near-zero aphid population at the time of emergence of the second generation may have contributed to their rapid dispersal.

1976 Study

Figures 4, 5 and 6 show the total number of *M. sexmaculatus* adults

Figure 3. Recovery of Adult and Immature Menochilus sexmaculatus (F.) After Release in Sample Plots Spaced at Distances of 1.5 m, 3.0 m, and 7.6 m.

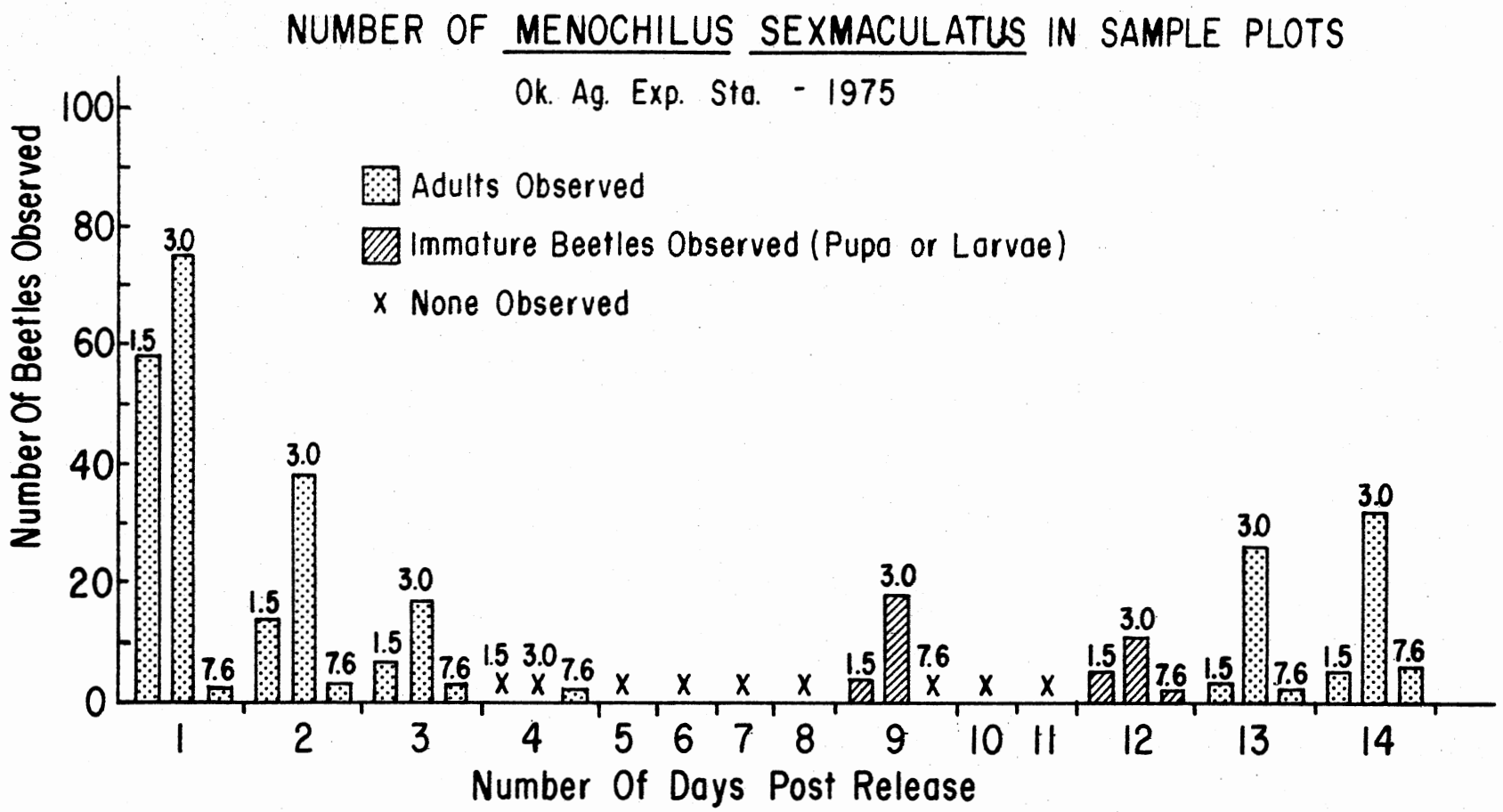

NUMBER OF MENOCHILUS SEXMACULATUS IN SAMPLE PLOTS
Ok. Ag. Exp. Sta. - 1975
Adults Observed
Immature Beetles Observed (Pupa or Larvae)
x None Observed
Number Of Beetles Observed
100
80
60
40
20
0
1.5
3.0
7.6
x
1 2 3 4 5 6 7 8 9 10 11 12 13 14
Number Of Days Post Release

Figure 4. Recovery of Menochilus sexmaculatus (F.) in Sample Plots in Field One Near Cushing, Oklahoma, 1976.

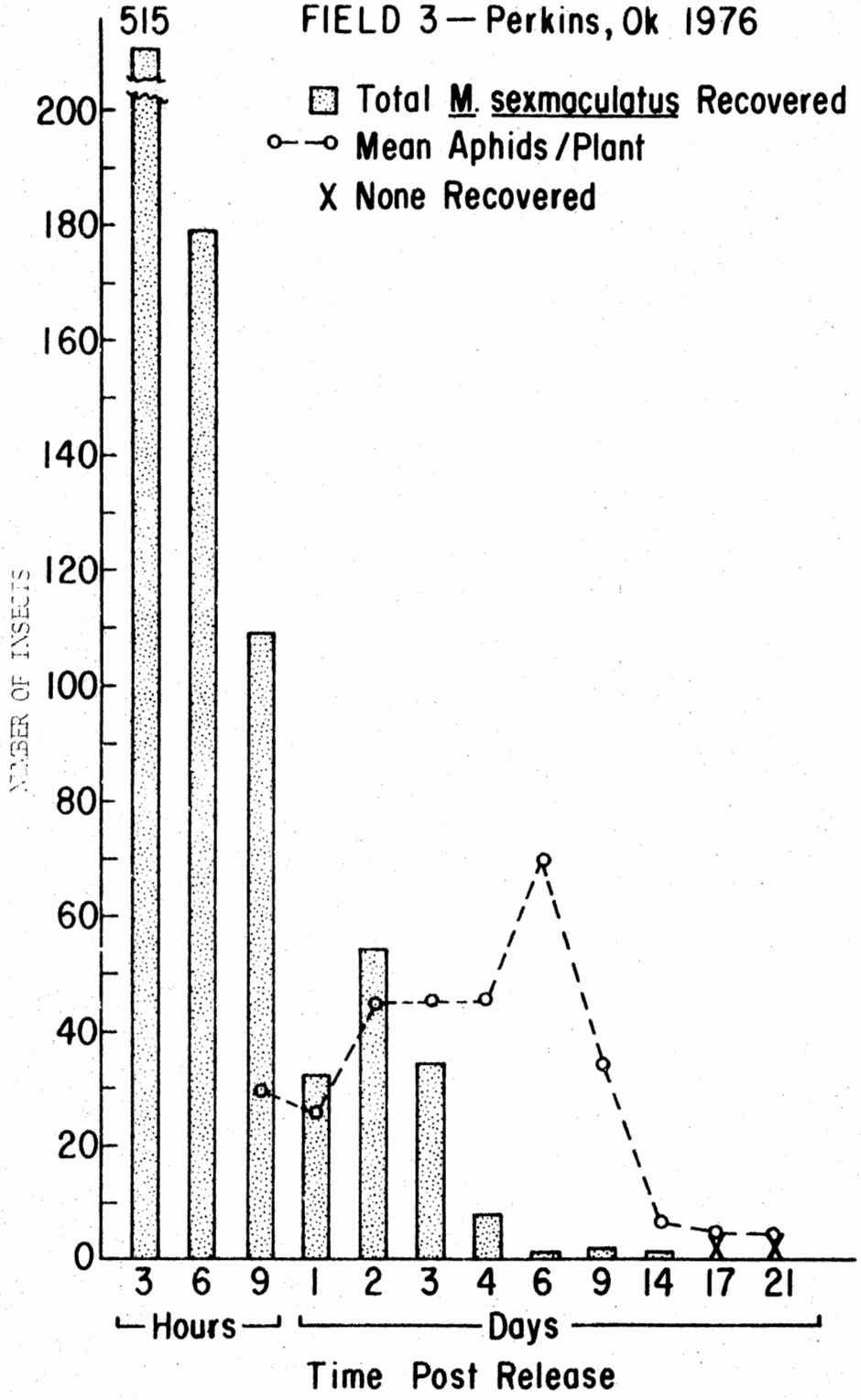

515
FIELD 3 — Perkins, Ok 1976
Total M. sexmaculatus Recovered
Mean Aphids/Plant
X None Recovered
NUMBER OF INSECTS
200
180
160
140
120
100
80
60
40
20
0
3 6 9 1 2 3 4 6 9 14 17 21
Hours
Days
Time Post Release

Figure 5. Recovery of Menochilus sexmaculatus (F.) in Sample Plots in Field Two Near Cushing, Oklahoma, 1976

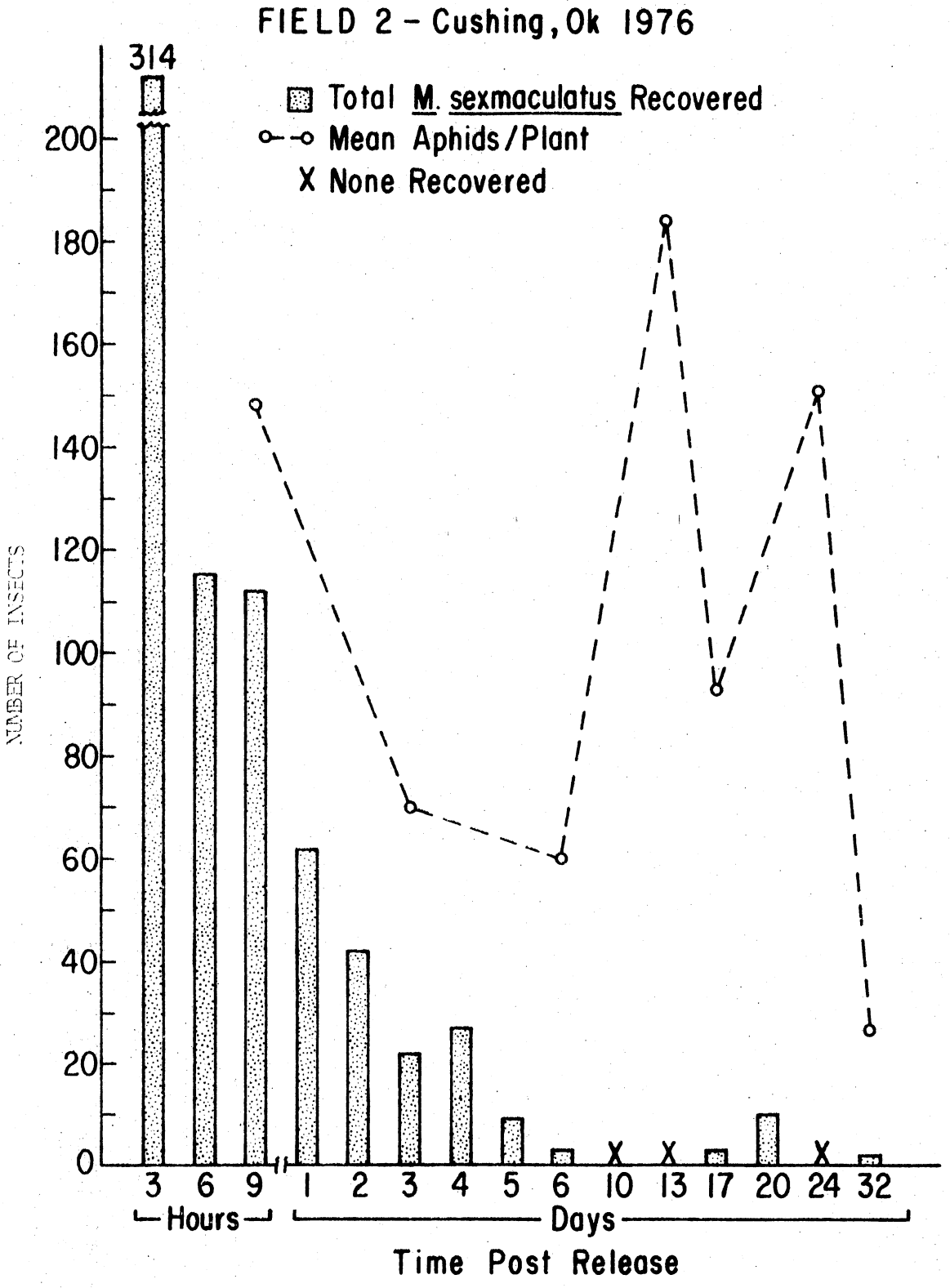
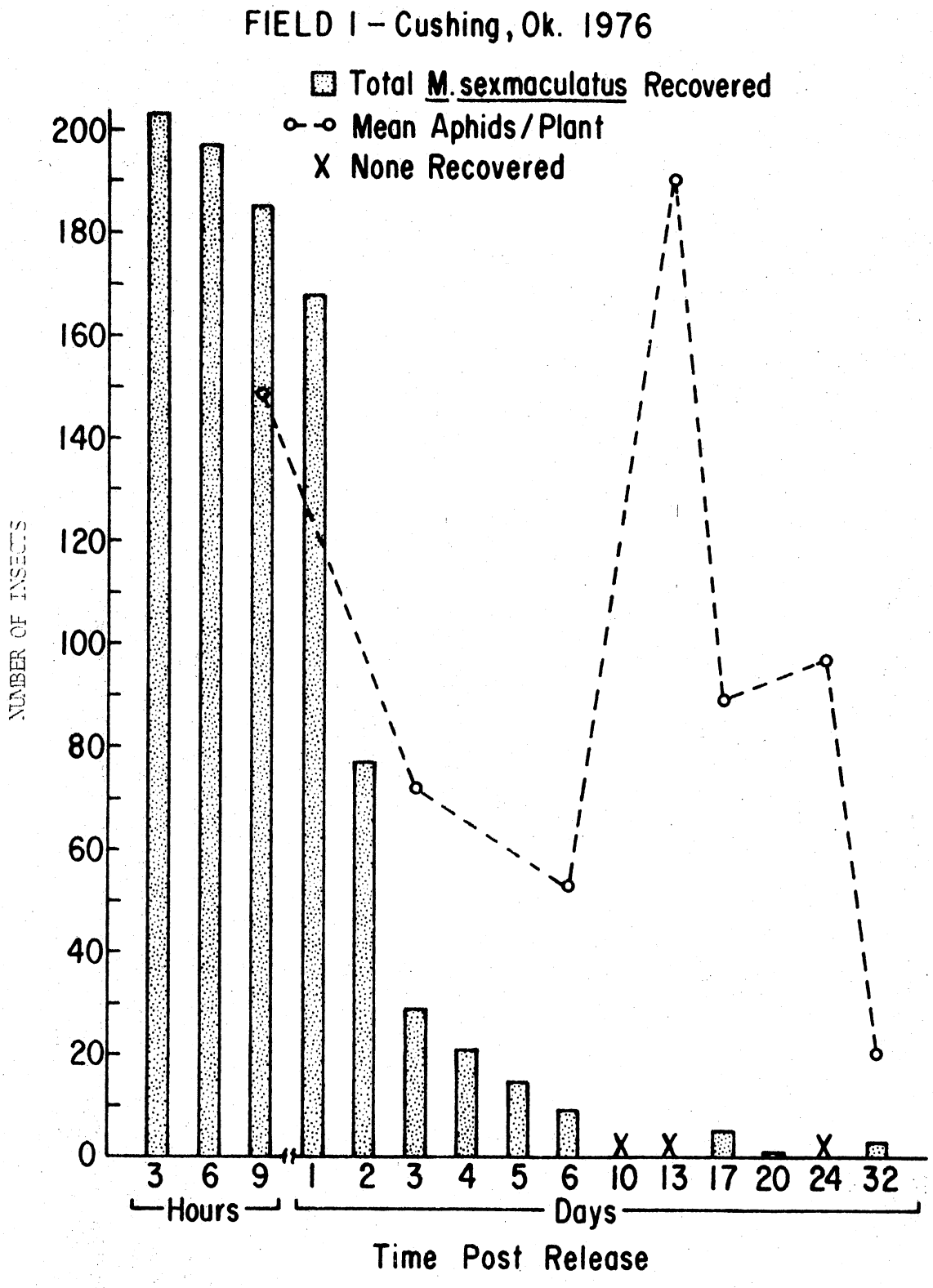

FIELD 2 - Cushing, Ok 1976
314
Total M. sexmaculatus Recovered
Mean Aphids/Plant
X None Recovered
NUMBER OF INSECTS
0
20
40
60
80
100
120
140
160
180
200
3 6 9 1 2 3 4 5 6 10 13 17 20 24 32
Hours
Days
Time Post Release

Figure 6. Recovery of Menochilus sexmaculatus (F.) in Sample Plots in Field Three Near Perkins, Oklahoma, 1976.


FIELD I – Cushing, Ok. 1976
Total M. sexmaculatus Recovered
Mean Aphids / Plant
X None Recovered
NUMBER OF INSECTS
200
180
160
140
120
100
80
60
40
20
0
3 6 9 1 2 3 4 5 6 10 13 17 20 24 32
Hours
Days
Time Post Release

recovered including those beetles remaining at the center of the release site and the mean number of aphids (S. graminum and R. maidis) per plant. In all three releases, movement of the beetles by crawling from the release point did not seem to show any directional trends. In both Field One and Field Two, beetles were found as long as 32 days post release and in Field Three as long as 14 days. Beetles were observed feeding, mating, and ovipositing during the day of release in Fields One and Two; however, in Field three, feeding and mating was observed, but no oviposition occurred. In Field One and Field Two, an F_1 generation was evidenced by the presence of larvae and pupae prior to the appearance of adults on 17, 20 and 32 days post release. In Field Three, no evidence of an F_1 generation was observed.

A Student's "t" test between the number of aphids inside plots and the number of aphids outside the release area for each day revealed no significant difference at the 5% level for all three Fields in 1976, though a noticeable reduction of aphids occurred near each release point. Aphids in Field One and Field Two declined steadily until 6 days after release then sharply increased at 13 days and ended with a final decline at 32 days.

The decline in aphid populations in Fields One and Two may not be due solely to the influence of released beetles since other factors (e. g. native predators and parasites, rainfall, wind, etc.) amy have been involved.

In Field Three (Figure 3) the aphid population maintained a much lower level than in the other two Fields. Low beetle reproduction in Field Three may have been a result of the relatively low aphid population. Peak aphid population in Field Three occurred after the beetles

had almost completely dispersed (6 days post release).

Flight observations taken in 1976 indicated that most beetles preferred to fly with the wind which was predominately from the S or SE (Table I). All northerly directions combined accounted for 96% of flights in Field One and 89% in Field Three. This relationship between wind and flight direction of coccinellids observed by Ali and Azam (1977) seems to be supported by observations of M. sexmaculatus.

In two releases of "estivohibernating" H. convergens collected in California, Starks et al. (1975) reported that 72% and 99% of released beetles "took to the wind and were soon lost from sight". The percentage of M. sexmaculatus observed flying within the first 6 h after release, 10% (of 536 beetles) in Field One and 6.4% (of 1014) in Field Three, is minor in comparison. The number of M. sexmaculatus remaining in the release area 24 h after release was 133 in 1975 (16%), 168 in Field One - 1976 (34%), 62 in Field Two - 1976 (13%), and 32 in Field Three - 1976 (3%). Kieckhefer and Olson (1974) only recovered 9 of 7175 released H. convergens after 24 hours (0.13%). This may suggest that M. sexmaculatus may be more sedate than H. convergens. However, comparison of the two species may be questionable since the H. convergens were field collected in the releases by Kieckhefer and Olson (1974) while the M. sexmaculatus in this study were laboratory reared.

Beetles were observed in plots at all distances sampled in all three of the 1976 releases including 24.4 m from the release point. This indicates an improvement in the 1976 sampling method over the sampling method used in 1975.

M. sexmaculatus has shown that (in three of four releases) it will remain in a given area sufficient period of time to complete at least one generation.

TABLE I

FLIGHT OBERSVATIONS OF M. SEXMACULATUS IN SORGHUM FIELDS INFESTED WITH S. GRAMINUM IN 1976 [a/] [b/]

Direction	%
FIELD ONE - CUSHING, OKLAHOMA	
NW	28
NNW	20
N	20
NE	14
NNE	8
WNW	4
ENE	2
SW	2
S	2
FIELD THREE - PERKINS, OKLAHOMA	
NW	38
N	26
NNW	11
S	8
WNW	8
NE	6
SE	3

[a/] Wind speed ranged 0-15 mph for both fields (predominately from the SE).

[b/] Aphid density at the time of release was 147.8 plant with 500 beetles released in Field One and 29.3/plant with 1014 beetles released in Field Three.

In addition, Ghani (1977) found M. sexmaculatus to remain longer in agricultural areas than any other cocinnellid of Pakistan. He designated this species as the most important of all predators in limiting populations of graminaceous aphids including the greenbug, S. graminum, since it remains active throughout the growing season. By the relatively slow dispersal behavior shown in this study, it is apparent that M. sexmaculatus has the same potential for greenbug control in the United States. However, releases of M. sexmaculatus in this study have apparently not been successful in establishment. Several possible explanations exist for the failure of this species to become established: (1) laboratory rearing has resulted in a narrowing of the gene pool causing decreased vigor, decreased competitive or prey searching ability and reduced adaptability to varying environmental conditions (Mackauer, 1976); (2) suitable alternate hosts are lacking; and (3) the relatively small numbers of released beetles and their progeny simply become so diluted that reproduction among subsequent generations did not occur. If large numbers of these beetles could be supplied by field collection or other means, establishment would be more likely.

Release and Establishment of Coccinella septempunctata L.

Releases

In 1975, a total of 4721 adult C. septempunctata was released in three counties at five different sites (see Table II for summary of releases). These beetles were collected during late summer and presumably were not in diapause but were no longer ovipositing. Generally, the beetles dispersed fairly rapidly and a few were found several days fol

TABLE II

RELEASES OF *COCCINELLA SEPTEMPUNCTATA* L. IN OKLAHOMA 1975-1979.

Release Site	Date	County	Habitat[1/]	No. Released	Intended Host Aphid
Perkins, OK. (PER)	05 Aug. 75	Payne	Sor.; Var.	1,125	*Schizaphis graminum* (Rondani)
Perkins, OK. (PER)	12 Aug. 75	Payne	Sor.;	725	*S. graminum*
W. of Stillwater, OK (FGH)	12 Aug. 75	Payne	Var.	245	*Dactynotus ambrosiae* (Thomas)
Perkins, OK. (PER)	18 Aug. 75	Payne	Var.	870	*S. graminum*
Stillwater, OK.(Campus)	18 Aug. 75	Payne	Var.	291	*Myzocallis kahawaluokalani* Kirkaldy
Idabel, OK.	19 Aug. 75	McCurtain	*Pinus* sp.	582	*Cinera* sp.
Burneyville, OK.	20 Aug. 75	Love	*Caryae* sp.	883	*Monellia* sp.
Perkins, OK. (PER)	15 Mar. 76	Payne	Var., Peas	15,997	*Acyrthosiphon pisum* (Harris)
Lake Carl Blackwell (LCB)	30 Oct. 77	Payne	Peas, Wheat	13,000	*A. pisum* & *S. graminum*

TABLE II (Continued)

Release Site	Date	County	Habitat[1/]	No. Released	Intended Host Aphid
Fowler, OK. (FOW)	04 Apr. 78	Lincoln	Alf.	6,500	A. pisum
Fowler, OK. (FOW)	18 Apr. 78	Lincoln	Alf.	6,279	A. pisum
Choska, OK.	19 Apr. 79	Wagoner	Alf.	11,002	Acyrthosiphon kondoi Shinji & A. pisum
Enid, OK.	23 Apr. 79	Garfield	Alf.	11,000	A. kondoi & A. pisum
Stratford, OK.	26 Apr. 79	Garvin	Alf.	11,000	A. kondoi & A. pisum
Welch, OK.	28 Apr. 79	Craig	Alf.	1,500	A. kondoi & A. pisum

[1/] Sor = Sorghum [Sorghum bicolor (L.)]

Alf = Alfalfa [Medicago sativa (F.)]

Var = Variety of crops (more than 3)

Peas = Austrian Winter Peas

lowing each release. Three hundred seventy of the 1125 beetles released near Perkins, Oklahoma, (PER) on 5 August 1975 were, were found dead within a 3 m radius of the release point 24 h after release. A search of the area following release gave no evidence of progeny.

Two releases were made on 12 August 1975; 725 adults were released in sorghum infested with greenbugs, Schizaphis graminum (Rond.) on the Oklahoma Agricultural Experiment Station near Perkins, Oklahoma, (ca 0.5 km from the 5 August release site); and 245 adults were released near the Forestry greenhouse (FGH) on Ambrosia sp. infested with Dactynotus ambrosiae (Thomas). Both releases of 12 August failed to produce progeny. However, beetles released at Forestry greenhouse remained and fed near the release site for at least one week. The relatively rapid dispersal was probably due to lack of sufficient cover at the Perkins release sites. No progeny were recovered following three other releases during August 1975 that were made at three different locations. Failure of C. septempunctata to produce progeny in 1975 was possibly due to the exhibition of univoltinism (Angalet, unpublished data) and thus, the adults, when released, were physiologically beyond reproduction.

On 7 November 1975, 27,000 adult C. septempunctata were placed in two wooden frame cages (2.5 m X 1.5 m X 2.5 m) filled with overwintering materials. Winter mortality totaled 11,003 (ca 41%) and on 15 March 1976 the surviving 15,997 adults were released in a 2 ha field of Austrian winter peas surrounded by a variety of other crops including wheat, peaches, and apples. Dispersal of the beetles following this release was much slower since cover and an abundance of aphids were present. An F_1 generation was recovered during the following weeks until vegetation was removed in preparation for summer crop planting.

On 30 October 1977, 13,000 beetles were released (1000/cage) from the "Small animal cages" placed along the hedgerows adjacent to both Austrian winter peas (ca 0.5 ha) and winter wheat (ca 25 ha) located near Lake Carl Blackwell (LCB). Many beetles emigrated from the cages to nearby leaf litter and grasses when temperatures were above 20°C.

In April 1978, two releases were made in an alfalfa field near Fowler, Oklahoma, (Lincoln County). The beetles were collected at the Hackensack Meadowlands, New Jersey, during March 1978, and were presumably initiating diapause termination when released. The first release on April 5 involved 6,500 adults and the release made on April 12 included 6,279 adults.

A total of 34,500 adult C. septempunctata were released in four locations in Oklahoma in 1979. These beetles were collected in late October 1978 at the Hackensack Meadowlands and remained in large overwintering cages prior to being liberated in April 1979. Releases of ca. 11,000 beetles were made at three locations: near Choska, Oklahoma, in Wagoner County, near Enid, Oklahoma, in Garfield County, and near Stratford, Oklahoma, in Garvin County. Additionally, a release of 1,500 adult C. septempunctata was made near Welch, Oklahoma, in Craig County. All releases in 1979 were made in alfalfa infested with Acyrthosiphon pisum (Harris) and Acyrthosiphon kondoi Shinji.

Recoveries

Numbers of recovered beetles listed in Tables III - V show only the numbers of beetles collected. A ">" indicates more beetles were observed at the collection site than actually were collected.

Table III lists recoveries of C. septempunctata in Payne County

TABLE III

RECOVERIES OF *COCCINELLA SEPTEMPUNCTATA* L. IN PAYNE COUNTY, OKLAHOMA, 1976.

Date	Location[1/]	No. Recorded[2/]	Habitat[3/]	Aphid(s) Present	Distance from nearest release[1/]
30 April	LCB	1 pupa	Wheat	None	13.3 Km (FGH)
05 June	FGH	2	Hedgerow	None	---- (FGH)
05 June	W Stw	2	Vetch	*Acyrothosiphon pisum* (Harris)	0.83Km (FGH)
15 June	W Stw	1	Alfalfa	*A. pisum*	2.5 Km (FGH)
27 Aug.	FGH	2	Hedgerow	None	---- (FGH)
03 Sept.	FGH	1	*Ambrosia sp.*	None	---- (FGH)
17 Sept.	FGH	1	*Helianthus sp.*	None	---- (FGH)
19 Nov.	FGH	1	Inside greenhouse	None	---- (FGH)
Total		11			

[1/] FGH = Forestry Greenhouse Area; LCB = Lake Carl Blackwell; PER = Perkins; CC = Cow Creek Area, W Stw = West of Stillwater, Oklahoma (but not at other sites); VT = Vo-Tech Area.

[2/] All *C. septempunctata* recovered were adults unless otherwise noted

[3/] Wheat = *Triticum aestivum* L.: Vetch = *Vicia* sp.; Alfalfa = *Medico sativa* L.

TABLE IV

RECOVERIES OF *COCCINELLA SEPTEMPUNCTATA* L. IN PAYNE COUNTY, OKLAHOMA, 1977

Date	Location[1]	No. Recorded[2]	Habitat[3]	Aphid(s) Present	Distance from nearest release[1]
12 Mar.	VT	>50 All Stgs.	Wheat	*Rhopalosiphum padi* (L.)	2 Km (FGH)
9 Apr.	FGH	>25	Hedgerow, vetch	*Acyrthosiphon pisum* (Harris)	---- (FGH)
20 Apr.	CC	1	Alfalfa	*A. pisum*	2 Km (FGH)
3 May	W Stw	1	Vetch	*A. pisum*	4 Km (FGH)
7 May	CC	1	*Convolvulus arvensis*	None	2 Km (FGH)
24 May	FGH	7	Vetch, clover	*A. pisum*	---- (FGH)
2 June	FGH	5	Vetch, clover	*A. pisum* *Therioaphis maculata* (Buckton)	---- (FGH)
5 Oct.	FGH	1	Hedgerow	None	---- (FGH)
26 Oct.	FGH	1	Bare ground	None	---- (FGH)

TABLE IV (Continued)

Date	Location[1]	No. Recorded[2]	Habitat[3]	Aphid(s) Present	Distance from nearest release[1]
22 Nov.	PER	1	Wheat	R. padi; Schizaphis graminum (Rond.)	---- (PER)

[1] FGH = Forestry Greenhouse Area; LCB = Lake Carl Blackwell; PER = Perkins; CC = Cow Creek Area; W Stw = West of Stillwater, Oklahoma (but not at other sites); VT = Vo-Tech Area.

[2] All C. septempunctata recovered were adults unless otherwise noted.

[3] Wheat = Triticum aestivum L.; Vetch = Vicia sp.; Clover = Trifolium sp.

TABLE V

RECOVERIES OF *COCCINELLA SEPTEMPUNCTATA* L. IN PAYNE COUNTY, OKLAHOMA, 1978

Date	Location[1]	No. Recorded[2]	Habitat[3]	Aphid(s) Present	Distance from nearest release[1]
15 May	CC	ca. 50 All stgs.	*Ambrosia* sp.	*Dactynotus ambrosiae* (Thomas)	---- (FGH)
19 May	FGH	1	VET;CLO	*Acyrthosiphon pisum* (Harris)	(FGH)
19 May	E. of LCB	19	ALF	*A. pisum*	2.5 Km(LCB)
19 May	LCB	16	WHE;PEA	*A. pisum*	---- (LCB)
24 May	CC	14	VAR		1.5 Km(FGH)
25 May	CC	13	ALF:CLO;JOH	*A. pisum* *Rhopalosiphum maidis* (Fitch)	1 Km(FGH)
25 May	VT	1	ALF	*A. pisum*	2 Km(FGH)
30 May	W Stw	2	CTW		.5 Km(FGH)
8 June	W Stw	8	VET	*A. pisum* *Therioaphis maculata* (Buckton)	4 Km(FGH)
8 June	LCB	5	PEA	*A. pisum*	---- (LCB)
8 June	W Stw	4	VET	*A. pisum*	7 Km(FGH)

TABLE V (Continued)

Date	Location[1]	No. Recorded[2]	Habitat[3]	Aphid(s) Present	Distance from nearest release[1]
8 July	PER	1	SOR	R. maidis	---- (PER)
27 July	FGH	2	Ambrosia sp.	D. ambrosiae	---- (FGH)
3 Oct.	CC	1	fence	None	1 Km (FGH)
9 Oct.	CC	1	grass	None	1 Km (FGH)
1 Nov.	CC	1	grass	None	.5 Km (FGH)
	Total	139			

[1] FGH = Forestry Greenhouse Area; LCB = Lake Carl Blackwell; PER = Perkins; CC = Cow Creek Area; W Stw = West of Stillwater, Oklahoma (but not at other sites); VT = Vo-Tech Area.

[2] All C. septempunctata recovered were adults unless otherwise noted.

[3] VET = Vetch (Vicia sp.); CLO = Clover (Trifolium sp.); ALF = Alfalfa (Medicago sativa L.); WHE = Wheat (Triticum aestivum L.) PEA = Austrian Winter Peas (Pisum sp.); SOR = Sorghum (Sorghum bicolor L.); JOH = Johnsongrass (Sorghum halepense); CTW = Cottonwood (Populus deltoides Marsh); VAR = Variety of Crops.

for 1976. The first recovery, a pupa found 30 April, 1976 near LCB, was taken to the laboratory and reared for determination. This recovery was made ca 13 km from the nearest release site (FGH). Ten other specimens were recovered west of Stillwater, Oklahoma, near the FGH during 1976.

In 1977, 92 total beetles were recovered (Table IV). All recoveries, except one beetle found near the Perkins release site, were made within 4 km of the FGH release site.

In 1978, 139 C. septempunctata were recovered at 9 different locations in Payne County (Table V). The recoveries at the "Forestry Greenhouse", "Cow Creek", "Vo-tech" areas and "West of Stillwater" were probably offspring from the beetles released at FGH in 1975 since none were later released at that site. Five beetles were recovered near the forestry greenhouse on 5 April 1979. These recoveries indicate that C. septempunctata has survived for four years west of Stillwater, Oklahoma. Populations appeared to be most concentrated in the FGH area.

Recovery of a single adult was made near the PER release site. This, when combined with the single adult recovered in 1977, make annual recoveries for two consecutive years after the last release and three consecutive years since the initial release at that location. Thus, establishment at LCB seems likely but not conclusive. Beetles recovered at LCB in 1978 were probably the progeny of those released 30 October 1977, however, the pupa found on 30 April 1976 may indicate establishment had already been accomplished by spread of those released at FGH site. Confirmation of establishment at LCB will be more definite if specimens are recovered in 1979.

Recoveries made near Fowler, Oklahoma, Lincoln County, following

a release in April 1978 indicate an F_1 generation was produced. Peak recoveries of C. septempunctata were made on 22 May and 1 June. Immatures were recovered as early as 1 May. Beetles were recovered on several occasions during the remainder of the season including 21 July (13 specimens), 4 August (1 speciman), and 11 August (6 specimens). No beetles were recovered after 11 August. Only a few aphids could be found at this time. Establishment of C. septempunctata at Fowler and at all four 1979 release sites is not certain until future recoveries are made.

Criteria for judging establishment of new introductions of natural enemies as temporary or permanent are not well defined. DeBach and Bartlett (1964) state that three years must elapse in order to conclusively claim establishment. In Payne County, Oklahoma, C. septempunctata satisfies this cirterion. Interestingly, the most successful establishment site is west of Stillwater (FGH), where only 245 C. septempunctata were released.

Nine species of aphids were found on vegetation associated with recoveries of C. septempunctata during 1976-78. Several other aphid specimens were collected on host plans different than those in Table VI but identifications could not be made since no alate forms were found. Generally, Acyrthosiphon pisum (Harris), Therioaphis maculata (Buckton), and Dactynotus ambrosiae (Thomas) were the most abundant aphid species in confirmed areas of establishment.

The importance of C. septempunctata in limiting populations of the greenbug is discussed by Susidko and Skylar (1974). Through several releases were made in areas containing greenbugs, no C. septempunctata were observed feeding on them in the field. Previous laboratory observations have shown that recovered C. septempunctata will feed on green-

TABLE VI

APHID SPECIES PRESENT WITH RECOVERIES OF C. SEPTEMPUNCTATA IN OKLAHOMA 1976 - 1978

APHID SPP	HOST PLANT
Acyrthosiphon pisum (Harris)	Vicia sp.; Medicago sativa L.
Rhopalosiphum padi (L.)	Wheat (Triticum aestivum L.)
Rhopalosiphum maidis (Fitch)	Sorghum bicolor L.: Sorghum halepense L.
Schizaphis graminum (Rondani)	S. bicolor; T. aestivum, Sorghum, Wheat
Macrosiphum euphorbiae (Thomas)	Chenopodium albinum
Dactynotus rudbeckiae (Fitch)	Rudbeckia amplexicaulis
Therioaphis riehmi (Boerner)	M. sativa
Therioaphis maculata (Buckton)	M. sativa
Dactynotus ambrosiae (Thomas)	Ambrosia sp.

bug (Cartwright, unpublished data) indicating that it is at least an acceptable prey of C. septempunctata. Differences in food habits of C. septempunctata reported by different authors might be explained by the existence of different strains of C. septempunctata.

Intra-field dispersal may be rapid as Ali and Azam (1977) found C. septempunctata to be a strong flier. Observations during this study and those by Angalet (unpublished data) indicate that the spread by this species to new areas was very gradual. This contrasts with the rapid dispersal of collected Hippodamia convergens (Guerin-Meneville) that aggregate in the Sierra Nevada Mountains (DeBach and Hagen, 1964). C. septempunctata appears to be univoltine in Oklahoma since no larvae or pupae have been recovered later than mid May. This coincides with the single generation per year produced in the Hackensack Meadowlands of eastern New Jersey which is the source of all C. septempunctata released in Oklahoma (Angalet, unpublished data). However, lady beetles introduced to Florida from the Meadowlands have apparently become bivoltine since their introduction, producing larvae as early as March (pers. comm., G. W. Angalet). Possibly, additional generations per year will be produced in Oklahoma since the climate of Oklahoma is intermediate to that of New Jersey and Florida, provided conditions for the production of an additional generation are present, e.g. adequate aphid populations and relatively mild environmental conditions. Most likely, one of the factors limiting the production of additional generations in Oklahoma is adequate moisture since beetles are rarely found during the dry months of late June through July. This may suggest that at least part of the population of C. septempunctata experiences a facultative aestivation during this period.

CHAPTER IV

SUMMARY

Research undertaken in this study is part of an effort to introduce exotic coccinellids to Oklahoma for biological control of aphid pests, especially the greenbug Schizaphis graminum (Rondani). This study has shown contrasting degrees of success in introducing the two coccinellids, Menochilus sexmaculatus (F.) and Coccinella septempunctata L., with the former being apparently unsuccessful in establishment, while the latter has successfully established itself in Payne County, Oklahoma.

A total of 2,898 adult Menochilus sexmaculatus (F.) were released in three sorghum fields infested with Schizaphis graminum (Rondani) from 1975 - 1976.

Studies of the dispersal behavior of Menochilus sexmaculatus (F.) showed the species to be a slow disperser, capable of remaining near the release site a sufficient amount of time to produce progeny. In two of four releases, released beetles were recovered as long as 32 days after release. Observations on flight behavior indicated that the majority of beetles flew with the wind even under relatively light wind conditions.

To date, no evidence of the establishment of M. sexmaculatus exists.

From 1975 - 1979, a total of 80,997 adult Coccinella septempunctata L. was released at 11 sites in eight counties including Payne,

Lincoln, McCurtain, Love, Garfield, Wagoner, Garvin and Craig Counties. Recoveries made for four consecutive years in Payne County confirm the establishment of C. septempunctata.

Aphid prey most commonly associated with recoveries of C. septem punctata were Acyrthosiphon pisum (Harris) Therioaphis maculata (Buckton) and Dactynotus ambrosiae (Thomas).

The impact of the establishment of C. septempunctata on Oklahoma aphid pests remains to be determined. Competitive interactions with native predators should also receive future attention in order to fully assess the contribution of this species to the control of aphid populations.

REFERENCES CITED

Ali, M. H., and K. M. Azam. 1977. Dispersal of the predatory beetle, Coccinella septempunctata L. J. Entomol. Res. 1(2): 158-63.

Angalet, G. W., and R. L. Jacques. 1975. The establishment of Coccinella septempunctata L. in the continental United States. Coop. Econ. Ins. Rep. 25: 45/48. 883-4.

Azim, A. and M. K. Ahmed. 1966. Studies on Menochilus sexmaculatus (Fabricius), a predator of aphids in Pakistan. Agr. Pakistan 17 (3): 309-16.

Aziz, S. A., S. N. Hyder, and M. H. Ali. 1969. Studies on the host preference of Coccinella septempunctata L. Indian J. Entomol. 31 (4): 350-3.

Bagal, J. R. and K. N. Trehan. 1945. Life history and bionomics of two predaceous and one mycophagous species of Coccinellidae. J. Bombay Nat. Hist. Soc. 4: 566-73.

Blackman, R. L. 1965. Studies on the specificity in Coccinellidae. Ann. Appl. Biol. 56: 336-8.

_____. 1967. The effects of different foods on Adalia bipunctata L. and Coccinella septempunctata L. Ann. Appl. Biol. 59: 207-19

Butani, D. K. 1958. Parasites and predators recorded on sugarcane pests in India. Ind. J. Ent. 20: 270-82.

Chelliah, S. 1971. Influence of Gliricidia maculata on the predatory coccinellid Menochilus sexmaculatus (F.) through Aphis craccivora (Koch). Ind. J. Ent. 33(1): 17-9.

Clayhills, T. and M. Markkula. 1974. The abundance of coccinellids on cultivated plants. Ann. Ent. Fenn. 40: 49-55.

Davidson, W. M. 1924. Observations and experiments on the dispersion of the convergent ladybeetle (Hippodamia convergens Guerin) in California. Trans. Amer. Ent. Soc. 50: 163-75.

DeBach, P., and B. R. Bartlett. 1964. Methods of colonization, recovery, and introduction. In: Biological Control of Insects Pests and Weeds (P. DeBach ed.). Chapman and Hall, London, pp. 402-26.

DeBach, P., and K. S. Hagen. 1964. Manipulation of entomophagous species. In: Biological Control of Insect Pests and Weeds. (P. DeBach ed.). Chapman and Hall, London, pp. 429-58.

DeBach, P. 1964. Success, Trends and Future Possibilities. In: Biological Control of Insect Pests and Weeds. (P. DeBach, ed.). Chapman and Hall, Longon. pp. 673-713.

Doane, J. F. 1963. Dispersion on the soil surface of marked adult Ctenicera destructor and Hypolithus bicolor (Coleoptera: Elateridae), with notes on flight. Ann. Entomol. Soc. Am. 56: 340-5.

Ewert, M. A. and H. C. Chiang. 1966. Dispersal of three species of Coccinellids in corn fields. Can. Entomol. 98: 999-1003.

Fenton, F. A. and R. G. Dahms. 1951. Attempts at controlling the greenbug by the importation and release of lady beetles in Oklahoma. Okla. Acad. Sci. Proc. 1951: 49-51.

Ghani, M. A. 1977. Natural enemies of graminaceous aphids. CIBC - Pakistan Station. Rawalpindi. Final Tech. Rep. 69 pp.

Gupta, R. S. and K. S. Kushwahea. 1970. Toxicity of some insecticides to the predator, Menochilus sexmaculatus (F.) (Coleoptera: Coccinellidae) Ind. J. Ent. 32: 379-81.

Gurney, B., and N. W. Hussey. 1970. Evaluation of some coccinellid species for biological control in protecting cropping. Ann. Appl. Biol. 65: 451-8.

Hagen, K. S. 1962. Biology and ecology of predaceous Coccinellidae. Ann. Rev. Ent. 7: 289-326.

Hamalainen, M., M. Markkula, and T. Raij. 1975. Fecundity and larval voracity of four lady beetle species. Ann. Entomol. Fenn. 42 (4): 124-7.

Hamalainen, M. 1976. Rearing the univoltine lady beetle, Coccinella septempunctata L. and Adalia bipunctata L. all year around in laboratory. Ann. Agric. Fenn. 15: 66-71.

Hamalainen, M. 1977a. Storing dormant Coccinella septempunctata L. and Adalia bipunctata L. adults in the laboratory. Ann. Agric. Fenn. 16: 184-7.

_____. 1977b. Control of aphid on sweet peppers, chrysanthemums, and roses in small greenhouse using the ladybeetles Coccinella septempunctata and Adalia bipunctata (Col., Coccinellidae). Ann. Agric. Fenn. 16: 117-31.

Hodek, I. 1973. Biology of Coccinellidae. Dr. W. Junk, The Hague. 260 pp.

Huffaker, C. B. and R. L. Doutt. 1965. Establishment of the coccinellid Chilocorus bipustulatus L. in California olive groves. Pan. Pac. Ent. 41(1): 61-3.

Johnson, W. L., W. H. Cross, J. E. Leggett, W. L. McGovern, H. C. Mitchell, and E. B. Mitchell. 1975. Dispersal of marked boll weevil: 1970-1973 studies. Ann. Ent. Soc. Amer. 68(6): 1018-22.

Jotwani, M. G. and K. K. Verma. 1969. Menochilus sexmaculatus (F.) as a predator of sorghum stem borer Chilo zonellus (Swinhoe). Indian J. Ent. 31: 84-5.

Kapur, A. P. 1939. Color variation of Chilomenes sexmaculata F. Indian J. Ent. 1: 109-10.

Kieckhefer, R. W. and G. A. Olson. 1974. Dispersal of marked adult coccinellids from crops in South Dakota. J. Econ. Entomol. 67(1): 52-4.

Laing, J. E. and J. Hamai. 1976. Biological control of insect pests and weeds by imported parasites, predators, and pathogens. In: Theory and Practice of Biological Control. (C. B. Huffaker and P. S. Messenger, eds.). Academic Press, New York. pp. 685-743.

Mackauer, M. 1976. Genetic problems in the production of biological control agents. Ann. Rev. Entomol. 21: 369-85.

MacLeod, J. and J. Donnelly. 1963. Dispersal and interspersal of blowfly populations. J. Animal. Ecol. 32: 1-32.

Maier, C. T. 1978. Dispersal of adults of the black vine weevil, Otiorhynchus sulcatus (Coleoptera: Curculionidae), in an urban area Env. Ent. 7: 854-7.

Modowal, C. N. 1941. A biological note on Chilomenes sexmaculatus (F.) Indian J. Ent. 3: 139-40.

Murdoch, W. W. and J. R. Marks. 1973. Predation by coccinellid beetles: Experiments on switching. Ecology 51(1): 160-7.

Parker, B. L., N. S. Ming, T. S. Peng and G. Singh. 1976. The effect of Malathion on fecundity, longevity, and geotropism of Menochilus sexmaculatus. Environ. Entomol. 5(3): 495-501.

Patel, R. K. 1968. Records of natural enemies of Sogatella furcifera Harath. Indian J. Ent. 30: 321-2.

Puttarudriah, M. and G. P. C. Basavanna. 1953. Beneficial coccinellids of Mysore, India. Indian J. Ent. 15: 87-96.

Radke, S. G., W. L. Barwad, and S. K. Mundiwale. 1977. Influence of age of predator Coccinella septempunctata L. and population densities of the host Rhopalosiphum maidis (Fitch) (Homoptera: Aphididae) on the rate of predation. Indian J. Agric. Sci. 47(6): 305-8.

Rajamohan, N. and S. Jayaraj. 1974. Studies on the reproduction of the coccinellid Menochilus sexmaculatus F. on four species of aphids. Z. Ang. Ent. 74(1973), 388-93.

Satpathy, J. M., G. K. Padhi, and D. N. Dutta. 1968. Toxicity of eight insecticides to the coccinellid predator Chilomenes sexmaculata (F.). Ind. J. Ent. 30: 130-2.

Shands, W. A., G. W. Simpson, and C. C. Gordon. 1972a. Insect predators for controlling aphids on potatoes. 5. Number of eggs and schedules for introducing them in large field cages. J. Econ. Entomol. 59(1): 810-17.

Shands, W. A., G. W. Simpson, and R. H. Storch. 1972b. Insect predators for controlling aphids on potatoes. 9. Winter survival of Coccinella spp. in field cages over grassland in Northeastern Maine. Ibid. 59: 1392-6.

Starks, K. J., E. A. Wood, R. L. Burton and H. W. Somsen. 1975. Behavior of convergent lady beetles in relation to greenbug control in sorghum. U. S. Department of Agric., Agric. Res. Serv. ARS-S-53, 9 pp.

Subramanayam, T. V. 1923. A note on color variation in a common lady-bird beetle Chilomenes sexmaculata F. Rep. Proc. 5th Ent. Meeting Pusa. pp. 363-4.

Sundby, R. A. 1968. Some factors influencing the reproduction and longevity of Coccinella septempunctata L. Entomophaga. 13(3): 197-202.

Susidko, P. I., and V. I. Skylar. 1974. Factors regulating the numbers of aphids on sorghum. Zashchita Rastenii 10: 26. (Abstract only).

Waddill, V. and M. Shepard. 1975. Dispersal of Podisus maculiventris nymphs in soybeans. Env. Ent. 4(2): 233-4.

Wolfenbarger, D. O. 1946. Dispersal of small organisms. Amer. Mid. Nat. 35(1): 1-152.

VITA

Bobby Oliver Cartwright

Candidate for the Degree of

Master of Science

Thesis: INTRODUCTION OF TWO EXOTIC COCCINELLIDS TO OKLAHOMA: INOCULATIVE RELEASES OF MENOCHILUS SEXMACULATUS (F.) AND COCCINELLA SEPTEMPUNCTATA

Major Field: Entomology

Biographical:

Personal Data: Born in Claremore, Oklahoma, February 28, 1956 the son of Harold and Betty Davis

Educational Data: Graduated from Ripley High School, Ripley, Oklahoma, in May, 1974; received Bachelor of Science in Agriculture degree, specializing in Entomology, from Oklahoma State University in May, 1978; completed requirements for the Master of Science degree at Oklahoma State University in July, 1979.

Professional Experience: Laboratory assistant, Department of Entomology, Oklahoma State University, 1973-1975. Research technician, Department of Entomology, Oklahoma State University 1975-1978; Graduate research assistant, Department of Entomology, Oklahoma State University, 1978-1979; Biological Aide, USDA-SEA-Beneficial Insects Research Laboratory, Summer 1977; State Coordinator - Tick Control, Division of State Parks, Summer 1978.

Professional Organizations: Entomological Society of America, Entomological Society of Canada and Sigma Xi.