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USE OF ATTRACTANT-BAITED TRAPS FOR MONITORING AND MASS TRAPPING OF ROSE CHAFER, MACRODACTYLUS SUBSPINOSUS (COLEOPTERA: SCARABAEIDAE), IN MICHIGAN PEACH ORCHARDS

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CHAD THOMAS PASTOR

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of the requirements for the

M.S. degree in ENTOMOLOGY

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By

Chad Thomas Pastor

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Entomology

2004

ABSTRACT

USE OF ATTRACTANT-BAITED TRAPS FOR MONITORING AND MASS TRAPPING OF ROSE CHAFER, MACRODACTYLUS SUBSPINOSUS (COLEOPTERA: SCARABAEIDAE), IN MICHIGAN PEACH ORCHARDS

By

Chad Thomas Pastor

The rose chafer, *Macrodactylus subspinosus* (F.), is a sporadic pest of fruit throughout Michigan. In 1999 and 2000 research was conducted on the relationship between rose chafer and improved trapping systems in Michigan peach orchards. Traps placed at any height were equally attractive to rose chafer. This is the first study to demonstrate the potential of mass trapping for control of *M. subspinosus* in peach and the first indication that benefits from mass trapping of this pest could be achieved in a single year of trapping. Overall, the mass trapping trials revealed that *M. subspinosus* adults quickly move into peach orchards upon emergence from overwintering sites. Substantial damage was recorded in June samples taken approximately two weeks after the first beetles were caught in perimeter traps. Mass trapping as a control strategy will therefore be most effective if traps are in place prior to the predicted first emergence of beetles. Control was best if traps were placed at least 12 m from any orchard border, with optimal catches within the 12 m to 24 m distance. Traps placed on grassy borders recorded more beetle captures than any other habitat recorded. Mean beetle captures were two-fold greater than in perimeter traps in these habitats compared to interior traps. Mean fruit injury in trapped orchards was significantly less than non-trapped orchards. A mark-and-recapture study would suggest beetles moved upwind from their release points. The most beetle were captured in traps adjacent to the release points.

ACKNOWLEDGEMENTS

I would like to thank Larry Gut, Rufus Isaacs, Mark Whalon, and Jim Flore, for their guidance and assistance as I worked to complete my Masters degree at Michigan State University. I would like to thank the West Central Michigan Crop Management Association for their cooperation and assistance identifying potential growers and locations that made this research possible. A special thanks to Peter McGhee, Mike Haas, John Wise, and their summer research teams for making the long trek north to Oceana County to assist in inspecting fruit and counting specimens. They provided much needed assistance from early in the morning, often late into the evening in unfavorable conditions. I would also like to thank my parents and family for their encouragement throughout my degree and their willingness to donate freezer space for unwanted, temporary guests. I would also like to thank my wife, Kristie, for her patience and understanding throughout the trying, but often rewarding times associated while pursuing my Masters degree. Lastly, I would like to thank my son, Keegan, for providing that last intangible that pushed me to finish.

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Literature Review

Rose Chafer Biology

The rose chafer, *Macrodactylus subspinosis* (F.) is an economically important beetle belonging to the Scarabaeid family. The genus *Macrodactylus* is small, containing a group of species commonly referred to as rose chafers. The two most common species are *M. uniformis*, the western rose chafer, and *M. subspinosus*, the rose chafer (Ritcher 1966). Rose chafer is also commonly known as the rose bug although its host range includes many more plants than the name suggests.

Distribution

The rose chafer is widely distributed across eastern and central North America, from southern Maine to Southern Carolina, and as far west as the Rocky Mountains (McLeod & Williams 1990, Brunner and Howitt 1981). In Ohio, rose chafer has been reported from regions with light, sandy soils (Williams et al. 1982). In Michigan, the beetles are distributed throughout the state, with higher populations found in sandy areas along the western shore of Lake Michigan.

Hosts

This insect is typically found in sandy soil areas, where the larvae feed on the roots of grasses, grains, weeds, and other plants. The adult rose chafer is an economic pest that feeds on ornamentals, flowers, vegetables, and fruit (Williams 1979, Williams et al. 1990, Smitley & Peterson 1993). In grapes, beetles cause injury to foliage, blossoms, and fruit. Adults usually emerge around the time of grape bloom and feed on blossom buds and flowers, although they also attack foliage at the end of bloom (Williams et al.

1982). Adults may nearly defoliate susceptible thin-leaved cultivars, such as the vinifera wine grapes (McLeod & Williams 1990, Williams et al. 1982). In apples, cherries, and peaches, adults feed on the fruit, causing catfacing damage, which may weaken fruit enough to drop prematurely. Damaged fruit that do not drop are often deformed and unmarketable.

Description

The adult rose chafer is 13mm in length with reddish, spiny legs. The body is a straw or fawn color, while the head and thorax is usually a light red. Rose chafer eggs are oval, shiny white and about 1mm in length (Mcleod 1990, Brunner & Howitt 1981). Larvae are C-shaped white grubs, about 20 mm in length. They are identified by a distinct rastral pattern with 4 to 10 preseptular, hamate setae (Ritcher 1966). The pupa is exarate, roughly 16mm in length, yellowish-white in color, and has the shriveled larval skin attached to its posterior (Brunner & Howitt 1981).

Life Cycle

Adults emerge in late May or early June in Michigan and have a life span ranging between 4-6 weeks. The adults feed and mate shortly after emergence (Brunner & Howitt 1981, McLeod & Williams 1990). Females mate and lay eggs continuously over a two-week period, with each female depositing 24 to 36 eggs each, depositing single eggs at a depth of 4 to 6 inches (Brunner & Howitt 1981, McLeod & Williams 1990). Two weeks after being deposited, the eggs hatch into small grubs that begin feeding on the roots of grasses, weeds, grains, and other plants throughout the summer, reaching full maturity by autumn (Brunner & Howitt 1981, McLeod & Williams 1990, Williams 1990). As the weather cools the soil, larvae move to deeper soil depths and form an earthen shell to overwinter in. In the spring, larvae move near the surface, feed for a short time, and then pupate in May. They remain in the pupal stage for two weeks and emerge sometime in late May or early June (Brunner & Howitt 1981, McLeod & Williams 1990, Williams 1990). There is only one generation per year.

Control

Historically, rose chafer has not been an economically important pest (Ritcher 1966), although adults have been reported to attack many different crops, including pear, cherry, cane berries, small grains, grasses, roses, grapes, apples, peaches, and some conifers (Riley 1890, Slingerland & Crosby 1922, Brunner & Howitt 1981). It appears that heavy infestations were usually localized problems, most likely due to the presence of prime larval habitat (light, sandy soils) in close proximity to the crop.

Most early literature on the control of rose chafer originates from Ohio, which has documented damage reports dating back to the late 1800's for peaches and grapes (Weed 1888). In Michigan, the first reports of economic damage were in the 1980's (Brunner & Howitt 1981).

Early control methods consisted of hand picking adults and regular whitewashing with freshly slaked lime (Weed 1888). Later, Johnson (1911) and Hartzell (1911) demonstrated the attraction of adults to sweetened arsenicals (baited with glucose and molasses). Johnson (1940) first reported trapping large numbers of adult chafer using Japanese beetle traps baited with an unknown attractant.

Eventually, DDT was proven effective for control of rose chafer (Cox 1947). The 1960's listed methoxychlor and DDT as control agents of adults (Mc Grew and Still 1972). After DDT was banned in the 1970's, methoxychlor remained the most commonly recommended control agent (McGrew & Still 1972). By the late 1970's, methoxychlor's effectiveness came into question. Around this time, Williams (1979) demonstrated adequate chafer control with methoxychlor, but its long term (7 day) residual value was not as good as the longer lasting microencapsulated methyl parathion. These compounds, along with azinphosmethyl, became the recommended control agents for rose chafer.

In 1996, the Food Quality and Protection Act raised the possibility that certain organophosphate and carbamate insecticides, such as azinphosmethyl, microencapsulated methyl parathion, and carbaryl, could lose their registration for use.

By August 2000, use of azinphosmethyl had been severely reduced for tree fruit and use of methyl parathion on most fruits was canceled (DiFonzo 2000). These losses leave only carbaryl and esfenvalerate for control of rose chafer on most fruits. Recently, some crop consultants have witnessed a decline in the effectiveness of these materials (J. Bakker, personal communication).

Cultural

Several cultural methods have been used for control of rose chafer. Hand picking is an option (McLeod & Williams 1990, Weed 1888) that can be effective when beetle numbers are low, such as in small gardens or plantings. Hand picking may not stop beetles from adjacent areas from flying to these plants and causing damage later. In the case of ornamental plants, cheesecloth netting may provide temporary protection from beetles (McLeod & Williams 1990).

Another possibility suggested by McLeod and Williams (1990) is plowing or cultivating prime larval habitat. The pupal stage is extremely sensitive to disturbance and it is thought cultivating prime habitat may be effective in destroying the pupae (McLeod & Williams 1990).

Trapping

Trapping of rose chafer was first tested by Johnson (1940), but no other information is available on trapping chafers until the 1980's. Trapping of adult chafer was first seriously studied by Williams & Miller (1982) at the Ohio Agricultural Research Center. Rose chafer trapping initially was used as a monitoring tool (Williams 1982). This work and subsequent work was most likely influenced both by Johnson's early work and work on Japanese beetle trapping (Fleming 1964, Ladd & Klein 1981).

Multiple trappings or mass trapping as a possible method for rose chafer control in grapes was first tested by Williams in 1988 (E. Lingenfelter, 1997, unpublished data) and expanded upon in subsequent field trials (Williams 1990, Williams, unpublished). Mass trapping of rose chafer in an Ohio vineyard has shown population reductions from over 93,000 beetles in 1988 to just over 4,000 beetles by 1992, where the population has remained at least until 1996 (E. Lingenfelter, 1997, unpublished data). Similar efforts to evaluate multiple trapping for control of Japanese beetle demonstrated some effectiveness in reducing numbers of beetles in isolated populations (Wawrzynski & Ascerno 1998). This method remains unfeasible for most commercial growers, however, due to the remaining population of beetles.

Chemical Attractants

Williams and Miller (1982) tested several compounds as possible rose chafer attractants and found hexanoic acid and valeric acid to be particularly effective. Tests for a female produced sex pheromone at this time yielded no results (Williams & Miller 1982).

In 1985, Williams et al. (1990) tested hexanoic and valeric acid in combination with three different esters: octyl butyrate, decyl butyrate, and nonyl butyrate. Significantly higher mean trap catches were recorded when the acids were combined with octyl butyrate used alone or in combination with the other two esters (E. Lingenfelter, 1997, unpublished data).

Further studies compared 20 compounds to the standard lure (valeric acid + hexanoic acid + octyl butyrate 1:1:1) (E. Lingenfelter, 1997, unpublished data). This led to the establishment of two new standard lures that contained 1-nonanol: valeric acid + 1-nonanol, 1:1; and valeric acid +hexanoic acid + octyl butyrate + 1-nonanol, 1:1:1:1 (E. Lingenfelter, 1997, unpublished data). In 1987, 36 more compounds were compared to the standards created in 1986 and results showed replacing 1-nonanol with trans-2nonen-1-ol increased trapping efficacy (E. Lingenfelter, 1997, unpublished data). Simultaneously, 29 new candidates were combined with valeric acid and tested against the old standard, valeric acid + hexanoic acid + octyl butyrate + 1-nonanol, 1:1:1:1. Alpha-ionone was included in a single treatment with a comparison. Alpha-ionone turned out to be a powerful attractant (E. Lingenfelter, 1997, unpublished data). Comparison testing in 1989 of alpha-ionone against old and new standards containing trans-2-nonen-1-ol against alpha-ionone and combinations containing it showed improved lure performance by the addition of alpha-ionone (E. Lingenfelter, 1997, unpublished data).

The resulting attractant (valeric acid + hexanoic acid + octyl butyrate + trans-2-

nonen-1-ol +alpha ionone, 1:1:1:1:1) was the best attractant available until at least 1997 (E. Lingenfelter, 1997, unpublished data). There is evidence that the effectiveness of the attractant may be related to a synergistic effect between the four components (E. Lingenfelter, 1997, unpublished data).

Another study to determine if females produced a sex pheromone was initiated in 1989. The study design consisted of five non-virgin females (virgins were not available) and a wet wick placed in a trap, while the control was a water-saturated dental wick placed in a trap (Williams et al. 1982). Baits were replaced on every other collection date. There was no significant difference between baited and control traps (E. Lingenfelter, 1997, unpublished data). Since the females were not virgin, the results do not eliminate the possibility of a sex pheromone because pheromone production may stop after the first mating encounter; this may not be unusual because females mate several times (E. Lingenfelter, 1997, unpublished data). The original research in 1982 by Williams tested for a sex pheromone with the use of virgin females that had been reared in the laboratory from larvae; the results showed no evidence to suggest a sex pheromone at that time (Williams et al 1982).

Trap Height

The potential effects of trap height on rose chafer captures have not been discussed in the literature. The standard protocol for trapping rose chafer adults is to place traps at a height of 1 m above ground, typically hung on steel rods (Williams et al 1982).

For Japanese beetle, traps placed at 13 cm capture significantly more beetles than traps placed at ground level or at 90 cm above ground level (Alm et al. 1996). Since

Japanese beetle is related to rose chafer, it is possible there is some optimal trapping height based on chafer movement and behavior.

Trap Color

Early research by Riley (1890) and Anonymous (1916) indicated pink and other light colored flowers were attacked by rose chafer, but dark-colored flowers were seldom damaged. *Macrodactylus pumilio* Burmeister, a related species from Brazil, is reported to prefer cream-colored or white flowers (Lordello 1951, Mariconi & Zamith 1952). Reports in Ohio suggested beetles were attracted to white clothing and trap color comparison tests were performed (Williams et al. 1990). Early research, following the methodology of Ladd and Klein (1986) showed chafers preferred yellow and white trap tops in comparison tests with trap tops painted red, green, blue, and black (Williams et al. 1990). A comparison of white and yellow baited and unbaited traps showed a significant preference for both the baited and unbaited white traps (Williams et al 1990). Standard Japanese beetle Elisco traps, provided by Trecé Company, were used. Only trap top colors changed, while the bottoms used were the standard green containers.

Beetle Removal

Japanese beetle research by Alm et al. (1996) showed that removal of beetles from traps before they die and decompose was necessary for maximum trapping effectiveness.

Mass Trapping in Peaches

Our research project resulted from Gerber Product's desire to produce a peach crop without broad-spectrum insecticides and the belief that some insecticides (specifically organophosphorous insecticides) would no longer be available for rose chafer control. This mandated the need for research into monitoring systems and mass trapping as an alternative to insecticides. Further, to improve efficacy of mass trapping and monitoring systems, we deemed it necessary to study the distribution and movement patterns of the rose chafer. The combination of a bleak future for organophosphorous insecticides and a desire to reduce insecticides in consumer goods created the need for this project and is the driving force behind almost all the research documented.

History of Attract-and-Kill

Attract-and-kill is a novel approach to control pests. This method entails using an attractant-toxicant combination, instead of traps, to reduce the population and prevent unacceptable levels of crop damage. This tactic relies on the response of individuals to synthetic attractants to remove them from the population. This approach has many of the same limitations as mass trapping, including lure attractiveness, population density and killing method effectiveness. The potential benefit of an attract-and-kill system is the mitigation of trap saturation in high density situations. The approach, however, still suffers from many of the constraints inherent to mass trapping, including maintenance of traps, costs of traps, lures, and attractants. Trap maintenance and high cost could be decreased if the system relies on attracting the insect to an insecticide treated plant surface, rather than a target device (Gut et al. 2004).

Attract-and-kill systems have been formulated and developed for beetles, moths, and flies. The most widely tested applications of attractants in conjunction with insecticides have been with tephritid fruit flies (Jones 1998). The systems evolved from attempts at mass trapping and the repeated failures because of trap saturation. Attract-and-kill control efforts for the olive fly, *Bactrocera oleae* Gmelin, in Greece, relied on a protein/insecticide-bait spray program. Unfortunately, the protein/insecticide-bait spray was highly attractive and toxic to natural enemies. Further refinement of the system focused on the use of target traps baited with a sex-pheromone dispenser or a food-attractant, reducing detrimental effects on natural enemies. This method of controlling *B. oleae* was effective at reducing fruit infestation (Gut et al. 2004).

Development of lure-baited control tactics for control of *Rhagoletis* fruit flies are ongoing in the eastern and mid-western USA. Initially, some success was found with attractant-baited sticky-coated red spheres for direct control of *Rhagoletis pomonella*. Commercial adoption of the tactic was hindered by the high maintenance associated with the traps for trap effectiveness. Further efforts focused on the use of small doses of toxicants instead of sticky substances. The red spheres were coated with low levels of imidacloprid, combined with the attractant, and have shown some success with controlling *R. pomonella* (Gut et al. 2004).

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Chapter 2

Improved trapping systems for Rose Chafer in Peach

Introduction

Rose chafer, *Macrodactylus subspinosus* (F.), is a pest of ornamental, flower, and fruit crops throughout the midwestern United States (Williams 1979, Williams et al 1990, Smitley and Peterson 1993). Rose chafer larvae are abundant in areas with sandy soils, where they feed on grass roots. Adults emerge from the soil in early June, and quickly move to surrounding vegetation to feed and mate (Williams et al 1990, Brunner and Howitt 1981). Fruit crops are especially vulnerable to damage associated with feeding by colonizing adults. The beetles attack grapes during blossom, destroying both the buds and flowers, resulting in diminished grape production or zero production (Williams and Miller, 1982). In apples, cherries, and peaches, rose chafer beetles devour young fruit, usually resulting in excavations on the surface, referred to as catfacing damage. Fruit severely damaged often causes fruit to drop.

Rose chafer was not considered a significant economic pest in Michigan until the 1980's (Brunner & Howitt 1981). Prior to this, heavy infestations were typically localized problems resulting from the close proximity of a fruit crop to prime larval habitat.

In response to increasing problems with rose chafer in grapes, Roger Williams and colleagues at The Ohio State University (Williams and Miller 1982, Williams et al. 1990) developed a system for monitoring rose chafer, which they subsequently tested as a tool for mass trapping. The initial trapping system consisted of a Japanese beetle trap (Trece, Inc., Salinas, CA) baited with 5 mg of a 1:1 blend of hexanoic acid and valeric acid floral lure. Multiple traps were placed around the perimeter of vineyards at predetermined distances to attract and mass trap large numbers of beetles and ultimately minimize fruit injury. Williams and colleagues reported mass trapping reduced damage to grapes over a period of 10 or more years.

Other researchers have developed similar tools to monitor and potentially control Japanese beetle. Traps designed to capture this pest are baited with a lure consisting of a pheromone and a floral attractant (Alm et al. 1996). In California, more than 10,000 traps are placed annually for detection purposes. Some researchers have claimed that mass trapping could be used to reduce beetle populations, although they stated it would be difficult to assess the effectiveness of such a program (Langford et al. 1940; Hamilton et al. 1971). Johnson and Kriegel (1995) demonstrated that large numbers of Japanese beetles could be captured in baited traps placed around the perimeter of Michigan grape vineyards. Although promising, this mass trapping program has not been further evaluated in fruit crops.

Trap color and the chemical composition of the attractant lure are known to influence the performance of rose chafer traps. Williams (1990) reported that adults had a significant preference for white traps over yellow traps. Rose chafer attractants mimic floral scents. Various chemicals have been screened to find optimal attractant lures (Williams and Miller, 1982, Williams et al. 1990) and the most effective for trapping beetles in grapes has been a 1:1:1:1:1 ratio of valeric acid, hexanoic acid, octyl butyrate, trans-2-nonenol, and alpha ionone (Williams 1991, unpublished). A 5-ml blend of the two most attractive chemicals, hexanoic acid and alpha-ionone, is commercially available for trapping rose chafer (Great Lakes IPM, Vestaburg, MI.)

Trap placement may also influence the effectiveness of rose chafer traps. Currently there is no standard protocol with respect to the proper height to place traps or the optimum positioning of traps relative to trees within the orchard being trapped. In contrast, research conducted on Japanese beetles demonstrated that there is an optimal height to place traps, roughly at the height of the surrounding grass (Alm et al. 1994; Alm et al. 1996). Alm and colleagues also determined that traps that were emptied daily caught significantly more beetles than traps that were not emptied daily.

The objective of the research reported herein was to develop traps, baits, and deployment strategies that would increase the effectiveness of trapping systems for rose chafer in peach. Our efforts focused on determining the effect of trap color, lures baited with various attractant blends or loading rates, and trap placement on the number of beetles captured.

Materials and Methods

Research Sites

Studies were conducted in five commercial peach orchards in Oceana County, Michigan or at the Michigan State University Trevor Nichols Research Center in Fennville, Michigan. Commercial orchard A was a 3-acre block located at (46°36', 86°28'). Adjacent habitats were comprised of woodlands, grassy fields, and a strip of rose bushes that divided the orchard from the adjacent road. The soil was fine sand, which is common to the area. Orchard B was a 6-acre block located at (46°36', 86°28'). Sweet and tart cherry orchards, a grassy field, and a woody forest bordered it. The soil composition was also light sand. Orchard C was a large block (15 acres) located at (43°32', 86°24'). A coniferous forest, sweet cherry orchard, and a grassy field bordered the orchard. The soil composition was a composite of sand and peat. Orchard D was an 8-acre block located at (46°36', 86°28'). The soil was light sand and habitats adjacent to the peach orchard included a commercial asparagus planting, a grassy field, a wooded area and residential yards. Orchard E was a 5-acre block located at (46°36', 86°28'). A row of pine trees, a grassy field, and a wooded area bordered it. The soil composition was also light sand.

Collection of Data and Analyses

With the exception of the lure study, all experiments were conducted with Japanese beetle traps (Trece, Inc. Salinas, CA) baited with a floral lure of 5 mg of a 1:1 blend of hexanoic acid and alpha-ionone. Traps were inspected and beetle capture recorded three times per week, unless otherwise noted. If beetle captures were low (less than 100), counts were made when the traps were emptied. When high numbers of beetles were captured (greater than 100), the contents of the trap were placed in marked plastic zip-lock bags, frozen, and beetles counted in the laboratory at a later date. Beetle captures were recorded from June 1 to July 27. Treatment effects were determined based on mean captures during the course of a particular experiment. Data were subjected to ANOVA (Fisher's Protected LSD) to determine significance between treatment means (SAS Institute, 1990).

Comparison of Trap Height

The trap height experiment was conducted in orchard A and consisted of 4 replications of three trap heights. Traps were hung on a 2.3 m section of 1.2 cm diameter PVC pipe. Three hooks were attached to the pipe to allow for placement of traps at 1 m, 1.5 m, and 2 m. To minimize position effects, traps were rotated each time they were inspected.

Effect of Trap Location

Traps were placed at various locations along a transect extending from the border of the peach orchard into adjacent habitat and from the border into the orchard interior. In 1999 at sites A, B and C, traps were positioned on the orchard edge (0 m) and at 12 m and 24 m outside and inside the peach block. Two transects were set up at each site for a total of six replications. In 2000, transects were set up at three locations. At sites B and C traps were positioned on the orchard edge and at 12, 24, 36, 48 and 60 m outside and inside the peach block. Traps outside the orchard at the third site (D) were positioned at the same distances as sites B and C. The smaller size of the peach orchard at this location, however, only allowed for traps at 12, 24 and 36 m into the orchard interior. Four transects spaced at least 30 meters apart were made at each site for a total of 12 replications. All traps were hung 1 m above the ground.

Attractants and Loading Rates

Three blends of volatile compounds were evaluated as potential attractants for rose chafer, hexanoic acid + alpha ionone, octyl buterate, and valeric acid + octyl buterate. Each attractant was tested at three loading rates, 2.5 ml, 5.0 ml, or 10 ml/lure. The lures consisted of a blank Loral Poly-Con deodorant dispenser containing Mini Poly-Con (Lermer Packaging Corp. Garwood, N.J.) saturated with the different attractant blends. Lures were loaded by Great Lakes IPM (Vestaburg, MI). Each attractant was tested at the three loading rates over a 10-14 d period as follows: octyl buterate (5-16 June), hexanoic acid + alpha ionone (18-28 June) and valeric acid + octyl buterate (30

June-15 July). The experimental design was a randomized complete block with two replications at each of three locations, A, B and C. To minimize position effects, traps were rotated each time they were inspected. Traps within a replication were spaced 12 m apart. Traps were suspended 1 m above ground level on metal stakes.

Trap Color

Direct comparisons of the attraction of beetles to appliance white or standard yellow traps were conducted in 1999 and 2000. In the first year, there were two replications at each of three sites (A, B and C) for a total of six replications. The number of replicates doubled in 2000. This entailed placing nine replications at one site (E) and three replications at another site (C). Yellow or white traps were spaced 10-12 m apart. Multiple replications at a particular site were spaced at least 20 m apart to minimize interference.

Larval Sampling

To evaluate the density and distribution of larvae, soil core samples were taken at the site with the highest adult captures, Site C. Soil samples (108 cubic cm) were taken with a golf hole cup cutter. Extracted soil samples were placed inside a white container and inspected for the presence of larvae or pupae. Ten random soil samples were taken at 12 m intervals from a 4m^2 area, starting 60 m from the orchard border into the adjacent habitat and moving 48 m into the orchard's interior. Four transects were made along the West border.

Results and Discussion

Trap Height

Mean captures of 287 to 343 adult *M. subspinosus* for the season were recorded in traps placed along the perimeter of peach orchards at 1, 1.5 or 2 meters above the ground (Table 2.1). Trap height did not significantly ($F = 0.439$; $df = 2, 6$; $P = 0.6580$) affect the number of beetles caught among the three positions tested. Similar captures of beetles in traps placed at 1, 1.5 or 2 meters suggests that trap height is not a factor in maximizing *M. subspinosus* beetle capture when traps are placed along the perimeter of peach orchards. The lack of a trap height effect for rose chafer is in contrast to the significant influence of trap height reported for another scarab, the Japanese beetle (Ladd and Klein 1982, Alm et al. 1996). Alm et al. (1996) reported that traps placed at a height of 13 cm above ground captured significantly more Japanese beetles that traps positioned at ground level or at 90 cm above ground level. The increased catch near ground level was a result of high captures of males flying just above the grass level in search of females. In mark recapture studies, I observed flight patterns of many beetles and the height of flight ranged from a few feet above ground to quick ascents well over 100 feet above ground level. In mass trapping trials in commercial peach orchards, I observed that *M. subspinosus* beetles would mate and feed on fruit throughout the canopy. Optimal trap height may be different where traps are placed in grassy fields well outside of the orchard or in cropping systems other than peach that have a very different canopy structure, such as grape.

Attractants and Loading Rates

Table 2.2 presents mean captures of beetles for the three experiments conducted in 2000. Each attractant or blend of attractants was tested at three loading rates, 2.5, 5 and 10 ml over the course of 2 weeks. There was no significant effect of loading rate on beetle captures for hexanoic acid + alpha ionone ($P = 0.4323$), octyl buterate ($P = 0.6753$)

or valeric acid + octyl buterate (P=0.6610). All of these compounds, used alone or blended, have previously been demonstrated to be powerful attractants for rose chafer (Williams and Miller 1982, Williams et al. 1990, Williams et al. unpublished data). From this study it can be concluded that the loading rate for these attractants does not have an effect on the strength of attraction for at least 2 weeks of trapping. The standard loading rate for various attractants used to monitor *M. subspinosus* is 5 ml. Lingenfelter (1997) reported that using smaller quantities of valeric acid, hexanoic acid, octyl butyrate or alpha-ionone resulted in a loss of attraction after three weeks. Higher loading rates were not tested, but he speculated that more than 5 ml of attractant might increase attraction. In my two-week capture study, 10 ml of attractant did not increase beetle captures. In conclusion, this work supports the recommendation of a 5 ml loading rate. A lower amount of attractant could be effective for trapping beetles to determine the start of flight and the level of pest pressure during the 2 weeks of peak activity in peach. However, use of a *M. subspinosus* trapping system for control of this pest requires a higher loading rate to maintain attraction for the 4 weeks beetles are present in peach orchards in Westcentral Michigan.

Trap Color

In 1999, there was not a significant ($F = 1.49$; $df = 1, 2$; $P = 0.35$) difference in mean beetle captures in yellow or white traps (Table 2.3). Over the 5-week course of the experiment, the white traps captured 11,000 total adult *M. subspinosus*, while the yellow traps attracted 8,862 beetles. Results were the same in the expanded study conducted in 2000, with over 43,000 beetles captured in both white and yellow traps and no significant difference in the affect ($F = 1.20$; $df = 2, 9$; $P = 0.35$) of the two colors on beetle captures in any of the comparisons (Table 3). Visual cues are known to improve the response of beetle species in which attraction involves aggregation on the host. The optimal color for boll weevil traps is yellow (Cross et al. 1976), the color that likely mimics the peak wavelength reflective of foliage. The strong attraction of yellow and white traps reported here and previously by Williams (1990) suggests that color is also an important cue for host searching *M. subspinosus* beetles. The host background, however, may modify the influence of color on attraction. *M. subspinosus* beetles move into grape during bloom and preferentially attack the white blossoms. Williams (1990) reported that white traps were superior to yellow traps for capturing beetles along the perimeter of grape vineyards. In contrast, in my study white and yellow traps were equally effective at capturing beetles along the perimeter of peach orchards. Movement of into peaches occurs well past bloom, with the beetles primarily aggregating on green fruit.

Larval Sampling

Overall, 34 out of 36 (94.4%) larvae were found 80 m or further from the orchard border (Figure 2.1). Only 1 larva (2.8%) was found inside the orchard (120 m), while the other larva was found at the border of the orchard (0 m). The patchy distribution of *M. subspinosus* larvae and the paucity of larvae within or in close proximity to peach orchards may reflect the female's choice of oviposition site. This scarab is reported to be most abundant in light, sandy soils (McLeod and Williams 1990). In choice tests, *M. subspinosus* preferred to deposit eggs in wetter soil than in drier soil (Allsopp et al. 1992). Cultivating or plowing may be effective in destroying overwintering stages of *M. subspinosus*. Unfortunately, my detection of most larvae well outside the orchard and in a patchy distribution suggests the likely ineffectiveness of plowing or cultivating for rose chafer control in Westcentral Michigan.

Trap Location

Experiments conducted in 1999 revealed that traps placed in areas outside the peach orchard (-12 and –24, Figure 2.2) caught significantly higher numbers of beetles than traps placed on the orchard border (0 m), or in the interior of the block (12 m and 24 m, Figure 2.1). Beetles catches were not significantly different at the two locations within the orchard.

A similar pattern of beetle captures in relation to the proximity of traps to the orchard perimeter was recorded in the 2000 experiments (Figures 2.3-2.5). Significantly higher beetle captures were recorded in traps placed outside the orchard (negative distances, Figures 2.3-2.5) than in traps placed at the border edge or inside the orchard (positive distances, Figs. 2.3-2.5). At site C significantly more beetles were captured 24 m outside the orchard than in any other trap location (Figure 2.4). There were no significant differences in beetle captures in traps placed at other locations outside of the peach orchard at this location. Overall, mean captures of beetles at site C were 1.5 to about 4 times greater in traps outside compared to inside the orchard. Adult beetle captures were not significantly different from the border (0 m) into the orchard interior (60 m) at site C. Similar results were obtained at sites B and D. No significant differences in beetle captures were recorded in traps placed at various positions within the orchard, or between 24 m and 60 m outside the orchard (Figures 2.4 and 2.5).

Adult beetle captures followed a very similar pattern in both years studies were conducted, as well as at individual test locations. Traps located in the areas outside of the peach orchards captured the highest amount of beetles, with catches decreasing as the traps were moved closer to and into the peach orchard. The general pattern also included similar beetle catches regardless of trap position within the orchard. The lone exception to this pattern was at site C, where substantially higher catches were recorded in traps placed 24 meters from the orchard edge. The effect of a unique geographical feature on beetle movement may have contributed to the results obtained at this location. Beetles tend to move from the adjacent habitats into peach orchards soon after emergence. The topography at this location included a hill, with the 24 m trap located at the highest point outside the orchard. It is possible that the traps positioned in valleys at 48 m and 12 m were less apparent to beetles heading for the orchard than the trap on the hill at 24 meters.

Traps placed within adjacent habitats outside of the orchard perimeter, preferably greater than 12 m, were consistently more effective in capturing *M. subspinosus* beetles than traps placed within the orchard interior. This results in part from the higher larval densities outside than inside the peach orchard. In addition, it appears that visual and olfactory cures provided by the trap are most affective in the absence of competing cues from peach trees. The attractiveness of peach begins to interfere with the trap performance as the beetles near the orchard, with the most significant effects occurring within 12 m of the perimeter.

For purposes of mass trapping, trap placement should focus on adjacent habitats as opposed to the perimeter and interior of orchards. This strategy is likely to maximize beetle catches, as the majority of them move into orchards from adjacent habitats, many from a great distance. In addition, I have observed that more rose chafer beetles are attracted to a trapped area than would otherwise be present in the absence of traps. Thus, placing traps a reasonable distance from the orchard may limit this trap associated damage.

Table 2.1. Attraction of *M. subspinosus* beetles to floral lure-baited Trecé traps placed at three different heights (1.0 m, 1.5 m, and 2.0 m).

Trap Height	Mean ± SEM
1.0 m	333.75 ± 35.741
1.5 m	287.00 ± 56.165
2.0 m	342.75 ± 41.171

Table 2.2. Capture of adult *M. subspinosus* beetles in Trecé traps baited different amounts of chemical attractants (2.5 ml, 5.0 ml, and 10.0 ml).

Lure/attractant dosage	Mean ± SEM
Hexanoic Acid + Alpha-ionone	
2.5 ml	1229.00 ± 210.06
5.0 ml	811.33 ± 147.942
10.0 ml	1037.83 ± 285.97
Octyl buterate	
2.5 ml	82.83 ± 27.78
5.0 ml	104.67 ± 30.14
10.0 ml	122.83 ± 36.14
Valeric acid + octyl buterate	
2.5 ml	50.00 ± 10.38
5.0 ml	69.50 ± 32.35
10.0 ml	78.83 ± 19.26

Table 2.3. Capture of adult *M. subspinosus* beetles in traps using two different colored Trecé beetle tops (white and yellow).

Trap top color	1st monitoring period 6/6/99-7/11/99	2nd monitoring period 6/6/00-7/11/00	3rd monitoring period 6/21/00-7/11/00	4th monitoring period 6/12/00-7/11/00
White	2075.2 ± 438.5	2221.5 ± 334.8	3246.0 ± 367.9	2183.0 ± 202.4
Yellow	1374.3 ± 262.1	2437.0 ± 458.9	3278.7 ± 424.2	2506.7 ± 288.7

Figure 2.1. Effect of trap location on adult beetle captures at sites A, B and C, Michigan, 1999. Traps were positioned on the orchard edge (0 m) and at 12 m and 24 m outside (positive values) and inside (negative values) the peach block. Means with the same letter are not significantly different (P=0.05, LSD test).

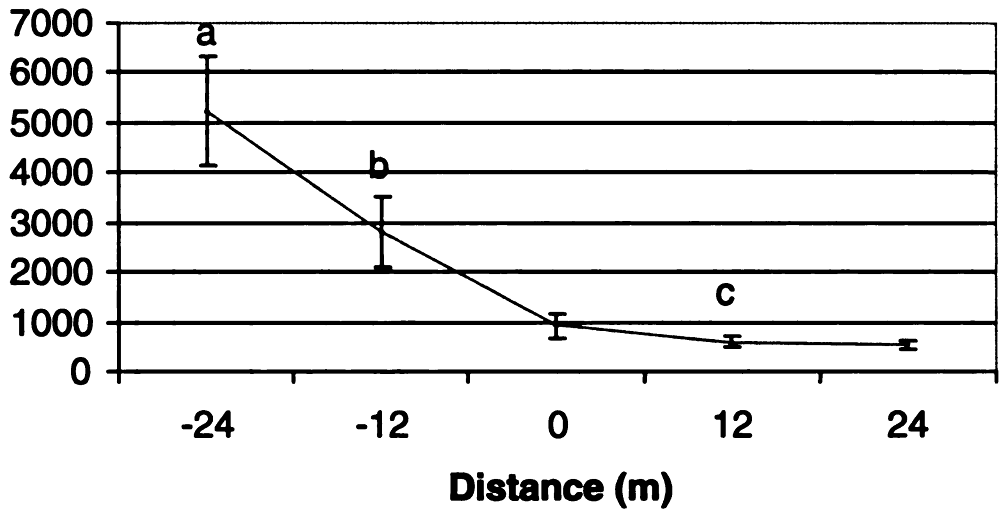


Figure 2.2. Effect of trap location on adult beetle captures at site D, Michigan, 2000. Traps were positioned on the orchard edge (0 m) and at 12 m, 24 and 36 m outside (positive values) and inside (negative values) the peach block. Means with the same letter are not significantly different (P=0.05, LSD test).

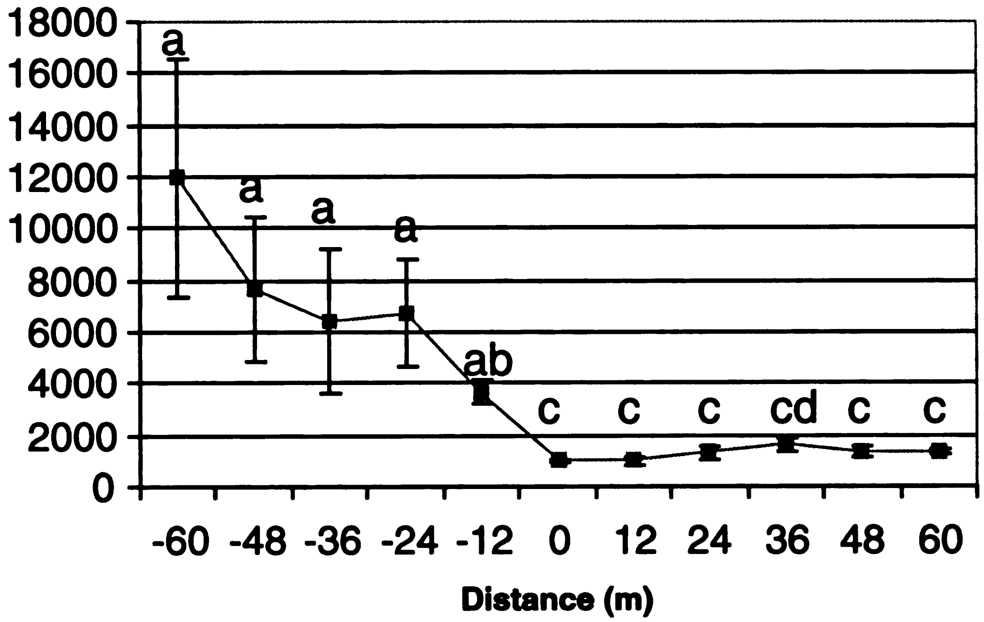


Figure 2.3. Effect of trap location on adult beetle captures at site B, Michigan, 2000. Traps were positioned on the orchard edge (0 m) and at 12 m, 24 36, 48 and 60 m outside (positive values) and inside (negative values) the peach block. Means with the same letter are not significantly different (P=0.05, LSD test).

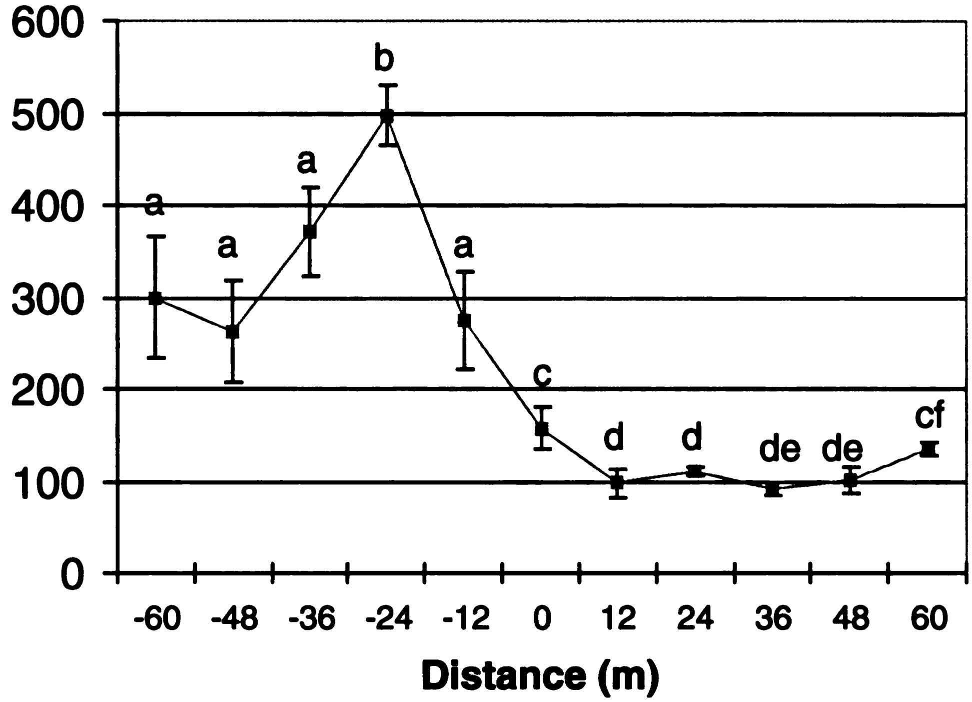


Figure 2.4. Effect of trap location on adult beetle captures at site B, Michigan, 2000. Traps were positioned on the orchard edge (0 m) and at 12 m, 24 36, 48 and 60 m outside (positive values) and inside (negative values) the peach block. Means with the same letter are not significantly different (P=0.05, LSD test).

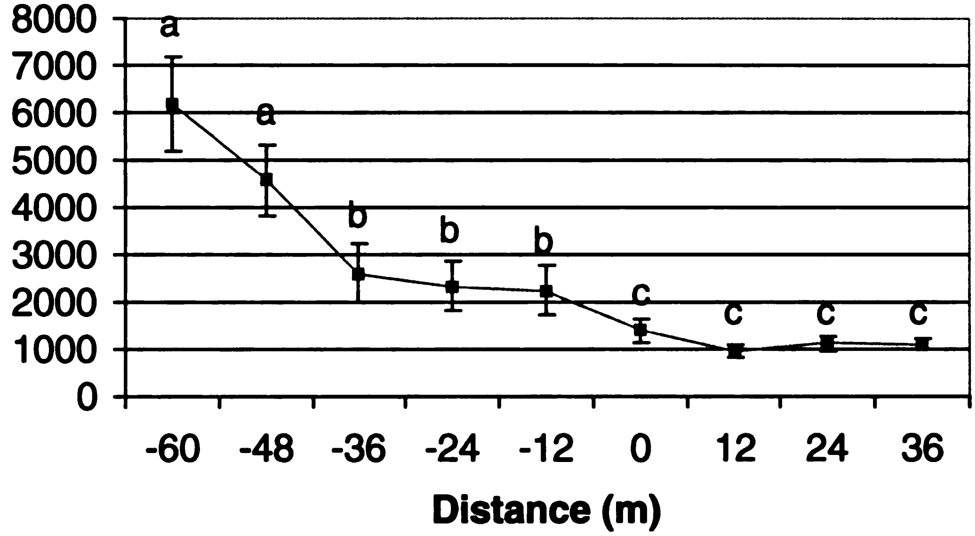
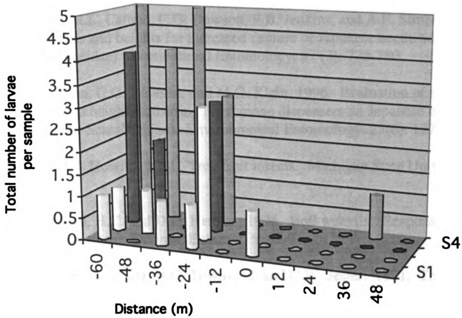


Figure 2.5. Comparison of soil samples taken at 12 m intervals and total larvae found (2000), Michigan. Total number of larvae found at each larval sampling area. Each sampling area consists of ten samples taken.



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Chapter 3

Mass Trapping for Rose Chafer Suppression in Peach.

Introduction

The rose chafer, *Macrodactylus subspinosus* (F.), is a sporadic pest of fruit throughout the midwestern United States (Williams 1979, Williams et al 1990, Smitley and Peterson 1993). The larvae feed on roots of grasses and weeds, while the adults feed on fruit, flowers, and foliage of plants (Williams 1979, Smitley and Peterson 1993). Rose chafer damage has been recorded on a diverse range of crops, including pear, cherry, cane berries, small grains, grasses, roses, grapes, apples, peaches, and some conifers (Riley 1890, Slingerland & Crosby 1922, Brunner & Howitt 1981). According to Brunner and Howitt (1981), the rose chafer was not recognized as an economically important pest in Michigan until the 1980's. Adult infestations and damage in the two most commonly attacked fruit crops, peach and grape, typically occur in orchards or vineyards in areas with sandy soils, which are prime larval habitat.

The early control strategies for adult rose chafer date back to the 1880s (Weed 1888) and included hand-picking adult beetles, as well as regular white-washing with freshly-slaked lime. In the early 1900's, both Johnson (1911) and Hartzell (1911) used sweetened arsenicals (molasses and glucose) to attract adult beetles. This is the first known reference to an attract-and-kill control strategy for this pest. Later, Johnson (1940) documented the first mass trapping of adult rose chafer, using a Japanese beetle trap and an unknown lure attractant.

However, the introduction of DDT in the 1940s probably curtailed research into mass trapping, as well as the need for mass trapping. By 1947, Cox had demonstrated that DDT was highly effective for control of rose chafer adults.

Further research and the development of organophosphorous compounds, such as methoxychlor, resulted in more insecticides confirmed as effective controls for chafer adults (McGrew & Still 1972). The subsequent ban on DDT in the 1970's resulted in methoxychlor being the most widely recommended material for rose chafer control (McGrew & Still 1972). By 1979, microencapsulated methyl parathion had surpassed methoxychlor in 7-day residual tests (Williams 1979). Microencapsulated methyl parathion, along with azinphosmethyl, quickly became the preferred choice to curb rose chafer damage and infestations.

Published documentation of rose chafer mass trapping efforts is non-existent for a span of at least 40 years from the time of Johnson's 1940 publication. In 1982, Williams and Miller published an article on traps as tools for monitoring the activity of rose chafer beetles. Their work and subsequent studies were strongly influenced by Johnson's research and Japanese beetle trapping studies (Fleming 1964, Ladd & Klein 1981).

Williams in 1988 (Lingenfelter, unpublished) first tested mass trapping of grape vineyards for control of rose chafer. This work was expanded upon in subsequent field trials (Williams 1990, Williams, unpublished). Mass trapping of rose chafer in an Ohio vineyard showed population reductions from over 93,000 beetles in 1988 to just over 4,000 beetles by 1992, where the population has remained constant at least until 1996 (Lingenfelter, unpublished). Similar efforts to evaluate multiple trapping for control of Japanese beetle demonstrated some effectiveness in reducing numbers of beetles in isolated populations (Wawrzynski & Ascerno 1998).

Passage of the Food Quality and Protection Act (FQPA) in 1997 initiated a series of decisions that ultimately limited the chemical options available for control of rose chafer. By August 2000, azinphosmethyl use in tree fruit had been restricted and the use of methyl parathion on most fruits was canceled by the USEPA (DiFonzo 2000). Further restrictions on which materials could be used for rose chafer control have been imposed by food processors, such as Gerber Products (Fremont, Michigan). Specifically, no carbamate or organophosphorous insecticides could be applied to peaches sold to Gerber Products.

The loss of insecticides available to peach growers due to resistance, new federal regulations or the strict requirements imposed by processors, provided the impetus to launch our research efforts on mass trapping of rose chafer in peach. Our goal was to develop a non-insecticide control program that would be provide fruit protection at least equivalent to that achieved through the use of insecticides. To accomplish this, we tested several trap deployment strategies in commercial peach orchards in Westcentral Michigan. Specifically, we evaluated the effectiveness of placing multiple traps around the perimeter or within the interior of the peach orchard and/or in chafer-infested habitats adjacent to the orchard. In addition, we used mark-recapture methods to examine the movement of beetles into peach.

Materials and Methods

All research sites were located in Oceana County, Michigan. A pest consulting firm, West Central Crop Management Association, recommended orchards based on scouting records from the previous season. Locations were divided into groups of three based on similarity of orchard setting and level of rose chafer fruit damage the previous season. Each site in a group of three was located within one mile of the other two sites.

One of three management programs, traps on border only, traps on border and within the interior, or no traps were randomly assigned to an orchard in each group. Details of the management programs are provided in the description of the 1999 and 2000 mass trapping studies.

Trapping Protocol

Elisco traps (Trécé, Salinas, CA) were baited with a floral lure consisting of a 1:1 blend of hexanoic acid and alpha-ionone (Great Lakes IPM, Vestaburg, MI). Traps were placed at each site approximately 2-3 weeks prior to first adult emergence. After emergence, traps were checked weekly. Traps were cleaned of any extraneous debris at this time. Trapped beetles were either counted on site or placed in marked plastic bags to be frozen and then counted at a later date. Frozen beetles were counted individually and the totals were recorded. If the total of beetles in a bag was over 2,000, the total number of beetles was estimated by weight. This involved weighing a group of 1,000 beetles 5 times, averaging the weight, then extrapolating the total number of beetles based on the total weight of all beetles from the bag.

1999 Mass Trapping Study

The 1999 study compared the efficacy of three rose chafer control programs. The first treatment was a border only trapping design. Plots treated in this manner had traps equally spaced around the entire orchard border at 12 m intervals placed 12 m from the plot border. The second treatment was a combination of border treatment with traps placed in the interior of the plots. Spacing around the plot remained the same as the first treatment. Interior traps were added at a rate of three per acre and spaced evenly throughout the plot. Interior traps were placed approximately 1-2 m between trees. The last treatment was the control plot in which traps were not deployed for rose chafer control. Insecticides were applied for rose chafer control in these blocks. Three to five traps were placed around the perimeter of the orchard to monitor beetle activity. All traps were checked, cleaned, and the beetles were stored for later counting in the laboratory.

Each treatment plot was sampled twice during the season for adult chafer-related fruit damage. Samples were taken in mid-June, before manual thinning of fruit and in July, after the thinning process. The protocol consisted of inspecting 30 fruit from each of 36 trees. The proportion of trees sampled on the border or in the plot interior varied slightly depending on the orchard configuration, however, a maximum of 20 exterior trees was inspected. The percent fruit damage for each treatment was calculated and means and standard errors compared to determine treatment effects.

Trap Location

For the eight orchards mass-trapped in 1999, the location of each trap was categorized with respect to the habitat in which it was placed. Four general habitats were identified for the purpose of classifying trap location: interior of the peach orchard, another fruit orchard, grass, or forest/woodland. Mean beetle captures in traps placed in each of the four habitat types were compared to determine the relationship between trap location and relative *M. subspinosus* activity.

2000 Mass Trapping Study

The 2000 mass trapping study expanded on the results obtained in 1999. In the second year we compared three treatments at four sites, including a modified border-only treatment, a field treatment, and a comparison site. The border only treatment retained the previous year's spacing of 12 m between traps along the border, with one key difference. Multiple traps were only placed on the "high risk" border and single monitoring traps were placed on the "low risk" sides. Risk of beetle activity on a particular border was determined based on adjacent plant habitats and the results of the previous year's experiment. Borders adjacent to grassy fields or where > 1% damage on perimeter trees was recorded the previous year were considered as high risk. The field treatment consisted of the border deployment of traps as previously described plus the addition of traps within the adjacent grass field. Traps were deployed in the field at 10 m intervals in lines extending out 40 m from the orchard edge. The last treatment was the control plot in which traps were not deployed for rose chafer control. Insecticides were applied for rose chafer control in these blocks. Three to five traps were placed around the perimeter of the orchard to monitor beetle activity. All traps were checked, cleaned, and the beetles were stored for later counting in the laboratory.

Chafer-related fruit damage was checked three times in this study, twice in June, before manual thinning and once July, after thinning. Fifty fruit were visually inspected on a total of 36 border and interior trees as in the 1999 study. The damage estimates were sorted into two categories, pre-thinning (mean of the June samples) and post-thinning (July sample). The percent fruit damage for each treatment was calculated and means and standard errors compared to determine treatment effects.

Mark–Release-Recapture

Adult beetles were obtained for mark-recapture studies using standard Elisco traps baited with a floral scented lure. Traps were placed at two Westcentral Michigan peach orchards with high rose chafer densities the day prior to a designated release time. Beetles were collected from traps within 24 hours, placed in a cooler and transported to the Trevor Nichols Research Complex (TNRC) in Fennville, MI.

Healthy beetles were sorted out from dead or lethargic beetles, separated into groups of 250, and each group marked with a different color of permanent paint. A single dab of paint was applied to the dorsal thorax of each beetle. Groups of 250 beetles were transported to the field in plastic containers (1 qt). Beetles were released from two locations adjacent to a 2.9 acre peach orchard (a 20 by 14 planting of 15 rows by 30 trees) at the TNRC by placing the container on the ground and removing the lid. Three releases were made from each location. The two sites selected for releases were in grass fields adjacent to the north and east borders of the peach orchard. Beetles were released from a central position relative to the orchard, but in the field 27 m from the orchard edge. The south and west borders were adjacent to a cherry and apple orchard, respectively. No releases were made from these locations. Beetles were recaptured in Elisco traps baited with a floral lure consisting of a 1:1 blend of hexanoic acid and alpha-ionone. Traps were placed in the two border rows and in two interior rows. Six traps were evenly spaced in each row for a total of 24 traps. Traps were inspected and beetles removed 24 h after a release and at least every two days throughout the 21-day study. The number of beetles captured, both marked and unmarked, were recorded on each inspection date.

Results

1999 Mass Trapping Study

Mean totals of 10026 or 12739 beetles were caught in the suppression traps in the border only or orchard-wide mass trapped peach orchards, respectively. Beetles were also captured in the limited set of traps placed on the perimeter of each of the comparison orchards. A mean total of 3083 beetles were caught in this set of monitoring traps.

Fruit damage caused by *M. subspinosus* feeding was recorded in all of the orchards in the June sample taken after approximately 2 weeks of beetle movement into orchards (Table 1). Levels of fruit injury ranged from a low of 0.33% in the orchard-wide treatment at site A to a high of 7.0% in the comparison treatment at site B. For all sites, mean fruit injury at this time was significantly lower in the peach blocks treated orchard-wide with traps than in the blocks treated with traps on the borders only or in comparison blocks treated with insecticides rather than traps. Similar levels of damage were recorded in the border trapped and comparison orchards.

Fruit damage caused by *M. subspinosus* feeding did not increase substantially between the June and July sample periods (Table 1). Levels of fruit injury in July ranged from a low of 0.88% in the comparison treated orchard at site D to a high of 7.9% in the comparison treatment at site A. For all sites, mean fruit injury levels in July were not significantly different in the mass trapped and comparison orchards. The border only and orchard-wide trapping programs did appear to suppress beetle populations at the two sites with the highest level of *M subspinosus* activity. Indeed at site A, mean fruit injury was two or three-fold greater in the comparison treatment than in the border only or orchard-wide treatments, respectively.

Trap Location

Traps placed in the interior of orchards caught significantly fewer beetles than traps placed along the orchard perimeter over the course of the 1999 experiment (Table 2). The highest catches were recorded in traps placed on the borders of peach orchards that were adjacent to grass habitats. Mean adult captures were three-fold greater in perimeter traps in grass habitats compared to interior traps. An intermediate level of beetle catches was recorded in traps placed on the borders of peach orchards that were adjacent to other fruit orchards or woodlands. Mean adult captures were two-fold greater in perimeter traps in these habitats compared to interior traps.

2000 Mass Trapping Study

Mean totals of 16639 or 45315 beetles were caught in the suppression traps in the border only or field trapped peach orchards, respectively. Very high numbers of beetles were also captured in the set of four traps placed on the perimeter of each of the comparison orchards. A mean total of 21598 beetles were caught in this set of monitoring traps.

As in 1999, beetle injury to fruit was recorded in all of the orchards in the June samples (Table 3). Levels of damage at site E were particularly high, with over 7.6% damage recorded in all three treatments. The lowest levels of damage for each treatment were also recorded at a single location, site G. Damage at site G ranged from a low of 0.39% in the border only treatment to a high of 2.38% in the comparison treatment. Mean fruit injury for the four sites in June was the same in the mass trapped and comparison orchards.

Post hand-thinning fruit injury counts taken in July revealed significant treatment effects. Damage was consistently lower in the border only and field treatments than in the comparison treatment (Table 3). Mean fruit injury for the four sites at this time was over two-fold lower in the peach blocks where traps were used to suppress beetle populations than in the blocks where traps were not deployed. Similar levels of damage were recorded in the border only and field treatments. Comparison of fruit damage estimates taken before hand thinning (June) and after hand thinning (July) indicate a general trend of less damage in the later than in the earlier sample.

Mark and Recapture

Very similar patterns of recapture were recorded following the three releases of beetles from the downwind (Michigan Automated Weather Network, http://www.agweather.geo.msu.edu/mawn) northern position (Figure 1). The overall recapture rate ranged from 4-12%. Of the beetles recovered, a majority was consistently caught in traps placed in trees closest to the point of release (across-row locations N3, N2, and N1 in Figure 1), or along the most western, and upwind, rows (Rows W2 and W1 in Figure 1). An average of 69% of the recovered beetles was caught in traps at these locations. Two traps (N2-W1 and N1-W1 in Figure 1) accounted for 49% of the total recaptured beetles. In contrast, only 9% of the total beetles recovered were from the south or southwest portion of the orchard. No beetles were caught in 10 of 13 traps located at these points furthest from the release.

The releases west of the peach orchard consistently resulted in a fairly even and widespread distribution of beetle recaptures. (Figure 2). The recapture rates for these three releases were higher than for the three northern releases, ranging from 6-13%. For all releases combined, failure to capture beetles was only recorded in one of the 24 trap locations. Release A had the most uniform pattern of beetle recaptures. Beetle catches were also widely distributed within and across rows in releases B and C, however, there was a pattern of high captures in the three most southerly cross-rows (S1, S2, and S3 in Figure 2). The two releases resulted in 67-77% of beetle catches in the southern cross-rows compared to 23-33% of beetles caught in the northern cross-rows.

Discussion

The data obtained from this two-year study indicate that the prospects are good for use of mass trapping as a management tactic for suppression of *M. subspinosus* in peach. All of the trap deployment strategies limited fruit damage caused by this pest to levels that were the same or below those obtained by using insecticides for control. This is the first study to demonstrate the potential of mass trapping for control of *M. subspinosus* in peach and the first indication that benefits from mass trapping of this pest could be achieved in a single year of trapping. Williams and colleagues in Ohio successfully controlled a population of *M. subspinosus* in grape by placing over a hundred Japanese beetle traps baited with a five component blend of attractants around the perimeter of the vineyard (Lingenfelter, 1997). However, three consecutive years of trapping was required to reduce beetle numbers to levels that did not cause economic damage.

By testing three strategies for deploying traps to mass trap beetles and protect fruit, I have highlighted strengths and weaknesses that can be used to fine-tune this management strategy. Overall, the mass trapping trials revealed that *M. subspinosus* adults quickly move into peach orchards upon emergence from overwintering sites. Substantial damage was recorded in June samples taken approximately two weeks after the first beetles were caught in perimeter traps. Mass trapping as a control strategy will therefore be most effective if traps are in place prior to the predicted first emergence of beetles. Placing traps in the interior of the orchard did not improve the level of fruit protection provided by the mass trapping management program. This is consistent with the finding that traps placed in the interior of the peach blocks caught substantially fewer beetles than traps placed along the perimeter or in grass fields adjacent to the orchard. Equal levels of fruit protection were achieved when traps were deployed only along the border adjacent to prime *M. subspinosus* habitat or along the orchard perimeter and within the high-pressure habitat. In a related study, I recorded significantly higher beetle catches in traps placed 40-80 meters from the orchard edge than in traps placed only 20 meters from the border. Despite these high catches well outside the orchard, the most efficient approach to mass trapping may be to deploy traps approximately 20 meters from the edge.

The mark and recapture experiments provided additional insights for optimizing the deployment of traps for the purpose of mass trapping *M. subspinosus* in peach. Recapture of beetles from grass fields to the north and east of the peach orchard revealed that orientation was primarily in the upwind direction. Beetles may have been responding to wind-carried host odors given off by the peach trees, or to the attractants in the lure. In either case, it appears that if borders of a commercial peach orchard were not reservoirs of overwintering beetles, trap deployment along these borders may not improve the effectiveness of a mass trapping control program. Beetles released from the grass field directly downwind of the peach orchard were recaptured throughout the block. This included movement of substantial numbers of beetles across the entire width of the block, a distance of 300 feet. Thus, successful mass trapping of commercial orchards with prime *M. subspinosus* habitat along a single border that is predominantly downwind may requiring placing traps around the entire perimeter rather than only along the high-pressure border.

Success in mass trapping *M. subspinosus* populations will depend on the efficiency of the traps used. Not all beetles attracted to a trap are actually captured. In observing beetle activity around traps, I noted fairly imprecise movement towards traps and a hit-or-miss style of landing. If the beetle hit the top of the funnel, they'd fall into the trap, but often beetles would hit the outside of the trap funnel or the attached container itself. For traps placed in fields adjacent to the orchard, beetles often clustered on or near vegetation surrounding the traps. It was not uncommon to see very high numbers of beetles feeding and mating in these locations. Beetles drawn to the vicinity of traps placed near the orchard perimeter or inside the orchard can be diverted to fruit in the nearby tree. Further studies are needed to determine the extent of damage in the immediate vicinity of traps. Regardless, a more efficient trap is needed to reduce the numbers of beetles attracted to the trap vicinity but not captured.

Few chemical options are available for rose chafer control due to federal regulation and restrictions imposed by food processors, such as Gerber Products. The most effective material, methyl parathion, is no longer registered. Mass trapping is unlikely to totally remove *M. subspinosus* populations from orchards or to reduce fruit damage to zero. However, my results suggest that damage to peaches can be held to economically acceptable levels by using a mass-trapping program. This, combined with other measures, such as a selective hand thinning program, makes non-chemical control a viable option for peach growers faced with a dwindling number of choices and an ever-demanding public supporting fewer pesticides in food. Further research to refine the techniques and tools used, as well as strong extension programs are needed to increase the acceptance of such programs by growers reluctant to use new control strategies.

Table 3.1. Comparison of *M. subspinosus* beetle captures and percent fruit injury in commercial peach blocks in which a border only, an orchard-wide (border plus the interior) or a no mass trapping program was used for control of this pest, Michigan, 1999.

Site	Area trapped	Total adults trapped	Number of traps	Mean fruit injury (%) June	Mean fruit injury (%) July
A	Border only	8619	36	4.50	3.10
	Orchard-wide	4250	48	0.33	2.17
	None			4.16	7.90
B	Border only	12792	29	4.50	3.11
	Orchard-wide	18799	44	3.16	3.50
	None			7.00	5.78
C	Border only	14534	48	1.55	1.44
	Orchard-wide	23916	81	0.44	1.67
	None			0.44	1.67
D	Border only	4157	37	1.11	1.77
	Orchard-wide	3989	44	1.11	1.67
	None			1.11	0.88
All (±SE)	Border only	10026 (2317)	38	2.92 (0.92)	2.36 (0.44)
	Orchard-wide	12739 (5085)	54	1.26 (0.66)	2.25 (0.43)
	None			3.18 (1.51)	4.06 (1.67)

Table 3.2. Mean adult beetle captures in traps placed in four habitats, Michigan, 1999.

Habitat	Mean Adults per Trap	Standard Error
Interior	33.88	7.62
Grass	90.67	12.45
Tree Fruit	61.26	18.01
Forest/Woodland	65.49	15.32

Table 3.3. Comparison of *M. subspinosus* beetle captures and percent fruit injury in commercial peach blocks in which a border only, field (border plus the adjacent field) or a no mass trapping program was used for control of this pest, Michigan, 2000.

Site	Area trapped	Total adults trapped	Number of traps	Mean fruit injury (%) June	Mean fruit injury (%) July
A	Border only	6002	10	1.72	0.78
	Field	18659	40	1.39	1.28
	None			4.37	3.39
E	Border only	32184	11	7.64	3.11
	Field	52320	56	8.86	3.50
	None			8.72	7.50
F	Border only	27100	12	2.23	1.50
	Field	105669	44	3.67	2.00
	None			3.14	3.60
G	Border only	1269	22	0.39	0.39
	Field	4612	62	0.95	1.56
	None			2.38	2.33
All (±SE)	Border only	16639 (7640)	14	3.00 (1.60)	1.45 (0.60)
	Field	45315 (22470)	55	3.72 (1.81)	2.09 (0.49)
	None			4.65 (1.42)	4.21 (1.13)

Figure 3.1. Comparison of M. *subspinosus* beetle captures for mark-and-recapture study released on three occasions (a, b, c) about 23 m from the north orchard edge.

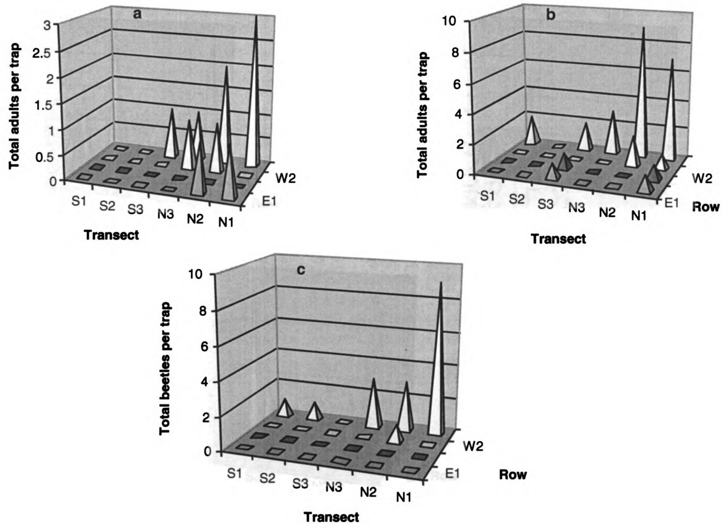
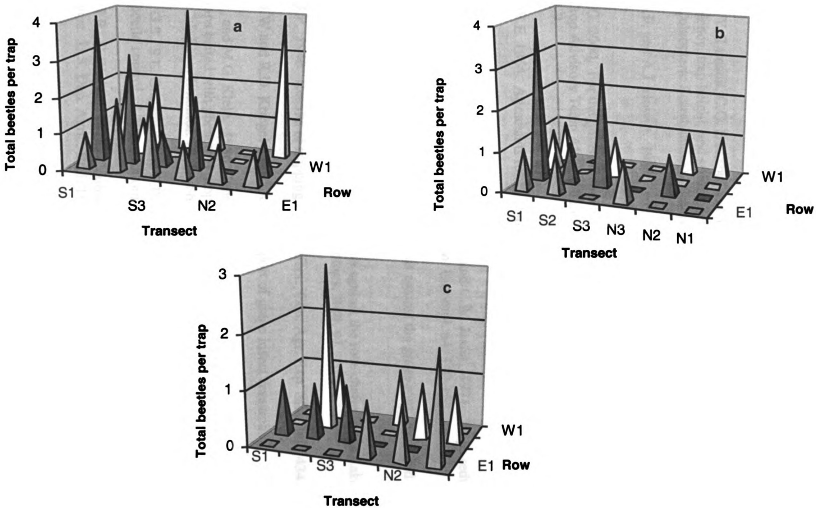


Figure 3.2. Comparison of M. *subspinosus* beetle captures for mark-and-recapture study released on three occasions (a, b, c) about 23 m from the east orchard edge.



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Appendix 1

Record of Deposition of Voucher Specimens*

The specimens listed on the following sheet(s) have been deposited in the named museum(s) as samples of those species or other taxa, which were used in this research. Voucher recognition labels bearing the Voucher No. have been attached or included in fluid-preserved specimens.

Voucher No.: 2005-01

Title of thesis or dissertation (or other research projects):

Use of Attractant-baited Traps for Monitoring and Mass Trapping of Rose Chafer, *Macrodactylus subspinosus* (Coleoptera: Scarabaeidae), in Michigan Peach Orchards.

Museum(s) where deposited and abbreviations for table on following sheets:

Entomology Museum, Michigan State University (MSU)

Other Museums:

Investigator's Name(s) (typed)

Chad Thomas Pastor

Date 1-26-2005

*Reference: Yoshimoto, C. M. 1978. Voucher Specimens for Entomology in North America. Bull. Entomol. Soc. Amer. 24: 141-42.

Deposit as follows:

Original: Include as Appendix 1 in ribbon copy of thesis or dissertation.

Copies: Include as Appendix 1 in copies of thesis or dissertation.
Museum(s) files.
Research project files.

This form is available from and the Voucher No. is assigned by the Curator, Michigan State University Entomology Museum.

Appendix 1.1

Voucher Specimens

Page 1 of 1 Pages

Species or other taxon	Label data for specimens collected or used and deposited	Number of: Eggs	Larvae	Nymphs	Pupae	Adults ♀	Adults ♂	Other	Museum where deposited
Macrodactylus subspinosus	Michigan, Oceana Co., Near Hart June 28th, 2000 Captured in baited Japanese beetle Elisco traps.					10			MSU

(Use additional sheets if necessary)

Investigator's Name(s) (typed)

Chad Thomas Pastor

Date 1/26/2005

Voucher No. 2005-01

Received the above listed specimens for deposit in the Michigan State University Entomology Museum

Curator Date 1/28/2005