

Principal Investigator: Russell Stocker

Pest Management Grants Final Report

Contract: 01-0205C

AERIAL RELEASE OF *TRICHOGRAMMA* TO CONTROL CODLING MOTH

Principal Investigator

**Russell Stocker
ARENA Pesticide Management
3412 Laguna Avenue
Davis, CA 95616**

Prepared

February 28, 2002

Prepared for the California Department of Pesticide Regulation

Principal Investigator: Russell Stocker

Disclaimer

The statements and conclusions in this report are those of the contractor and not necessarily those of the California Department of Pesticide Regulation. The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products.

Principal Investigator: Russell Stocker

ACKNOWLEDGMENTS

Key Personnel

Carolyn Pickel

Nick Mills, Ph.D.

Dave Ramos

**This report was submitted in fulfillment of DPR contract 01-0205C,
Aerial release of *Trichogramma* to control codling moth,
by Russell Stocker of ARENA Pesticide Management,
under the sponsorship of the California Department of Pesticide Regulation.
Work was completed as of February 28, 2003.**

TABLE OF CONTENTS

Title Page	1
Disclaimer	2
Acknowledgments.....	3
Table of Contents	4
Abstract.....	5
Executive Summary.....	6 - 7
Report.....	8 - 17
Appendices	none

ABSTRACT

Work by the principal investigator during the 1998-2001 growing seasons demonstrated the technical success of metering and applying *Trichogramma* parasitized *Ephesia* eggs, in conjunction with an adhesive, from an aircraft to adhere *Trichogramma* parasitoids to the foliage of walnut trees. *Trichogramma* also have been demonstrated to provide control of codling moth damage in walnuts, particularly when used in conjunction with mating disruption protocols..

This project has provided aerial release of *Trichogramma* parasitoids for an additional year in conjunction with the Walnut Pest Management Alliance (PMA) Work Plan, whose personnel provided monitoring, timing, and designed the various strategies described below. The principal investigator provided the parasitoids (and their releases) for the third generation releases (four), reducing costs to growers. The principal investigator also provided the Isomate CTT ties, the aerial Isomate applications, and the Checkmate and Hercon applications described in the report. The Checkmate and Hercon materials were provided by the manufacturers.

The goal of the PMA Work Plan is to demonstrate and implement reduced-risk pest management systems in walnuts statewide and to communicate these strategies to the walnut industry. The use of *Trichogramma* to control codling moth is one component of these strategies. During the 2002 season a total of 96.1 acres were used in the demonstration protocols. All test plots received treatment with pheromone material for mating disruption (utilizing different methods of pheromone application) and half of these test plots received releases of *Trichogramma* in the third generation. These protocols were compared to plots where conventional pesticides were used and to control plots where no pest control was implemented.

Unfortunately, there is no funding in the PMA Work Plan for the aerial release protocols, although there are funds, strategies and personnel for excellent field monitoring. The goal of this proposal was to provide an additional year of aerial releases of *Trichogramma*, as well as the demonstration of an aerial method to apply the pheromone material to the walnut canopy, with the goal of controlling codling moth.

Demonstrating an additional year of success of a reduced-risk pest management strategy has improved the likelihood of adoption by the walnut industry.

EXECUTIVE SUMMARY

Cydia pomonella, codling moth, is a serious exotic pest in walnuts and other crops in California. California produces virtually all the commercial walnuts in the United States on over 200,000 acres in 20 counties, with an annual crop value of over \$280 million. The Food Quality Protection Act will eliminate or reduce the use of commercial products such as Guthion and similar organophosphates that currently control codling moth populations. Therefore, alternative strategies, such as the use of *Trichogramma*, must be developed. Two major challenges to the implementation of *Trichogramma* in walnuts have been 1) how to place the parasitized eggs in the orchard canopy where the codling moths are found, and 2) how to do so economically. Previous work has demonstrated the technical feasibility of metering and applying *Trichogramma* parasitized *Ephestia* eggs (parasitoids) from an aircraft, in conjunction with an adhesive, to adhere *Trichogramma* parasitoids to the foliage of walnut trees. *Trichogramma* also have been demonstrated to provide a measure of control of codling moth in walnuts, and that control may be improved when combined with other Integrated Pest Management (IPM) strategies, such as pheromone-based mating disruption. This project has provided the aerial release of *Trichogramma* parasitoids and aerial pheromone application demonstrations, under controlled and monitored conditions, in conjunction with the Pest Management Alliance (PMA) Work Plan for California Walnuts, to answer these questions.

In cooperation with the Walnut PMA, four timed releases of *Trichogramma* parasitoids were made over half of the total of 96.1 acres of walnuts located in three orchards and involving growers in two counties. The strategies used during the 2002 season for codling moth control were: 1) mating disruption using Checkmate applied (sprayed) by air, 2) mating disruption using Isomate applied using an aerial automated pheromone dispenser, 3) mating disruption using Hurcon's Laminat, Disrupt® CM-Extra laminate, applied using an aerial automated pheromone dispenser, 4) Isomate Mops applied by hand using a cherry picker, 5) Isomate ties applied by hand using a cherry picker, and 6) grower standard, all of which were compared to control plots where no codling moth control measures were implemented.

Monitoring of the codling moth population is an important component in the success of these reduced-risk strategies. Without accurate monitoring, implementation of the reduced-risk strategy can be ill-timed and subsequent control rates are inadequate for the method to be acceptable on a commercial scale. The Walnut PMA was responsible for the monitoring protocols throughout the season and determined the pheromone and/or *Trichogramma* release dates. A second component of these reduced risk strategies is the ability to apply the strategy once monitoring has determined the optimum timing of the method. For a fourth year, there were no problems with the *Trichogramma* release system, which provides rapid and accurate (both in location and rate) releases of the parasitoids onto the walnut canopy. The success of a second season of the aerial application of pheromones has been particularly exciting.

Principal Investigator: Russell Stocker

For these reduced-risk strategies to be adopted commercially, they must be affordable. Monitoring is costly and reduced-risk strategies continue to be more costly per acre than conventional pesticides. In this fourth year of trials, one-time aerial applications of pheromone dispensers has been utilized for cost and efficacy comparison with conventional pheromone impregnated ties. By using mating disruption during the first and second generations, followed by *Trichogramma* in the third generation, we have overlapped two control methods. The effectiveness of pheromone dispensers for mating disruption decreases in the third generation. At the same time, the *Trichogramma* hatch from the parasitoids and begin parasitizing the codling moth larvae that are present. This strategy has provided good control results, exceeding the control observed with conventional pesticides in three of the ten test plots and equaling it in another. Mating disruption alone equaled or exceeded the control observed with conventional pesticides in four of the ten test plots, although these were not necessarily the same plots that received *Trichogramma*.

Finally, together with the Walnut PMA, the principal investigator has demonstrated the aerial release of *Trichogramma* and the aerial application of pheromone dispensers to be an effective component of reduced-risk strategies to control codling moth in walnuts. The results of these investigations have been disseminated to the walnut industry through various publications and meetings where the results of the program were well received.

REPORT

1. INTRODUCTION -- Identification and Significance of the Problem

Codling moth, *Cydia pomonella*, is a major exotic pest of walnuts, apples and pears in California and elsewhere in the United States. It was introduced from Eurasia and has spread rapidly, becoming a major problem in three quarters of the California counties where walnuts are grown. There is a distinct race of codling moth with a preference for walnuts and a life cycle that is well synchronized with the development of early walnut cultivars such as Serr, Payne, Ashley and Chico. The nuts of these varieties mature early enough to support first generation larvae. Codling moths produce three generations per year and larval damage from the first generation is believed to be responsible for nut drop in June. Nut meat damage caused by third generation larvae is seen at harvest and is more easily quantified.

Control of codling moth is fundamental to the management of other insect pests in walnuts. Cultural or biological controls are not satisfactory on a commercial scale at this time. Current management depends on monitoring pest populations to determine optimum times to apply conventional pesticides. Present control methods vary from grower to grower. Some use organophosphates and carbamates alone, which involves two applications of Lorsban (chlorpyrifos) during the first generation in the spring followed by a single application of Guthion (azinphosmethyl) during each of the two subsequent insect generations. Other growers will alternate the use of organophosphates and carbamates in one year with the use of pyrethroids, such as Asana, in the following year. Unfortunately, the organophosphate and carbamate pesticides also eliminate the natural enemies of destructive aphids, mites and scale insects making additional chemical applications necessary to control these pests. The pyrethroid materials have been found to have long acting residual effects which negatively impact beneficial insects such as *Trichogramma*. Current practice results in over 300,000 lbs of active ingredient being applied annually in walnut orchards in California¹ at an estimated cost of \$150 per acre, excluding application and labor costs.

Guthion, the principal insecticide used against codling moth in the United States since the 1960's, has a long residual life and high mammalian toxicity.² Its effectiveness against codling moth has declined over the last few years, especially in the San Joaquin Valley, indicating the codling moth is developing resistance to this and potentially a range of other synthetic insecticides.^{3,4} This reinforces the need for improved biological control methods.

California produces virtually all the commercially produced walnuts in the United States with over 205,000 acres in 20 counties dedicated to walnut production. Annual crop value is \$280 million, placing walnuts among the top five in California's fruit and nut crops.^{5,6,7}

Principal Investigator: Russell Stocker

Conventional methods for the release of *Trichogramma* involve the refrigerated shipment of pupae, ready to emerge as adults, inside parasitized grain moth eggs (*Ephesia sp.* or *Sitotroga sp.*), known as parasitoids, which are glued to perforated cards (~100,000 parasitized eggs or a minimum of 50,000 females/card). The cards are broken into ~2.5 cm squares (~15,000 females/square) on-site and distributed by hand in orchards by stapling the squares to leaves or by incubating the parasitized eggs in paper wedge cups, which are then set out after the adults emerge (2-5 days). Both the card and cup practices are highly labor intensive and slow and, therefore, prohibitively expensive on a commercial scale.

Pheromone-based mating disruption is one Integrated Pest Management (IPM) strategy for codling moth control^{8,9,10} that has worked well in apples and pears. The pheromone dispensers that are so successful in apples and pears are placed in the orchards by hand. Unfortunately, pheromones as a stand-alone strategy have not been as successful in walnuts, particularly because there is no acceptable placement method that is fast and cost effective. This is due to the number of acres involved, and the much larger size of the trees (and subsequent large volume of air which must be permeated with pheromone). Pruning towers have been used to place pheromone dispensers in small test plots. They have proved to be slow (1-3 man-hours/acre @ \$8/hour), costly (~\$25/hour for the tower plus labor costs) and require a certain degree of skill/experience to operate safely. In addition, enough towers simply do not exist to apply this strategy on a commercial scale. Another pheromone application method that was tested involved the application of a paraffin/ pheromone emulsion using a ground-based sprayer. In limited test plots, this strategy also proved to be too slow for commercial applications.

At the close of the 2001 season, results were very encouraging showing that *Trichogramma* in conjunction with a soft pesticide (such as Confirm) provided an acceptable level of codling moth control. Work by the Walnut Pest Management Alliance (PMA) during the 2002 season has shown *Trichogramma* combined with mating disruption to provide an excellent potential for control. This is a safer approach, having virtually no impact on ground water or runoff, and no concerns from spray drift. The challenges, therefore, are to be able to apply these strategies to the larger acreages in a timely manner and for these strategies to be reasonably affordable to the walnut growers. We have applied these strategies to over 96 acres in the 2002 season with excellent technical success - all the application/release protocols were accomplished without difficulty, and with reasonable control rates in most cases. Approximately half of the test plots demonstrated equal or better control than the grower standard and approximately half demonstrated less control than the grower standard. Overall, the average codling moth damage of the pheromone only plots was 1.42% and of the pheromone + *Trichogramma* plots was 1.41%, compared to the average grower standard of 1.02%, although two locations did not report the grower standard results. With a history of moderate codling moth populations, these non-reporting sites would expect 1-1.5% damage bringing the average grower standard to approximately 1.19-1.20%.

2. PROJECT OBJECTIVES

- A. The specific objectives for this proposal were to provide aerial release of *Trichogramma* parasitoids as well as the aerial application of pheromones, to demonstrate the success of these systems and strategies in controlling codling moth in walnuts during a subsequent growing season.

The goal of the Walnut PMA Work Plan is to demonstrate and implement reduced-risk pest management programs in walnuts statewide and to communicate these strategies to the walnut industry. The use of *Trichogramma* to control codling moth is one of these strategies. Previous release protocols have been prohibitive because they were labor intensive and slow, and, therefore, both costly and less effective. The aerial release strategy is comparably priced and very fast, which has increased the potential for adoption of this method of control. This proposal provided the technical expertise to place the *Trichogramma* parasitized *Ephestia* eggs in the upper canopy of the walnut trees, where the codling moths are present, in order to effect control of this significant pest without the use of conventional pesticides such as organophosphates. This proposal also provided a larger scale demonstration of three different aerial application strategies using pheromones for mating disruption.

In cooperation with the Walnut PMA and based on the protocols described below (Table 1), the investigator made aerial applications of pheromones to 96.1 acres of walnuts in three orchards in two counties (Table 2). The investigator also made subsequent releases of *Trichogramma* parasitoids over 48.1 acres of walnuts located in these three orchards. By reducing the number of releases, cost per acre has been kept steady. The investigator provided the *Trichogramma* parasitoids and the Isomate CTT ties. Checkmate and Hercon were provided by the manufacturer. These products are described in detail below.

Data was collected by the Walnut PMA team on nut damage only. All plots were monitored throughout the season using pheromone-baited traps. The percent of codling moth damage from each site for each protocol, with and without *Trichogramma* is shown below in Table 3. The combination of *Trichogramma* with pheromone-based mating disruption continues to appear to be a particularly promising strategy.

- B. Communicate the success of this strategy to the industry

This objective also has been accomplished. As described in detail below, the Walnut Pest Management Alliance has been proactive in communicating this reduced risk pest management strategy at multiple forums of growers, farm advisors, to field scouts, pest control advisors (PCAs), and BIOS projects.

3. RESULTS

- A. Provide aerial release of *Trichogramma* parasitoids, in conjunction with an adhesive, to walnut orchards participating in the Walnut PMA .

Earlier work conducted by Nick Mills and Carolyn Pickel has demonstrated that *Trichogramma* do not perform adequately as a stand-alone method during the first generation, resulting in higher canopy counts in the second and third generations. Therefore, during the 2000 season "soft pesticides" such as Confirm were used during the first and second generations followed by *Trichogramma* in the third generation. This strategy was successful, but fairly expensive (in both parasitoids and air time/labor) due to the number of releases made. In the 2001 season, the number of releases was reduced to determine if this lower-cost approach would provide adequate control, especially in conjunction with the use of the Isomate ties. It was found that if the ties are applied in April, they last to almost the end of the season. By releasing *Trichogramma* to coincide with the last generation, the thought was that the overlap would provide adequate codling moth control. This combination and overlap approach provided the best data and reduced the cost of the control strategy. The specific protocols that were implemented in the 2002 season were determined by Carolyn Pickel, Walnut PMA Field Team Coordinator, and are detailed in Table 1.

Table 1: Test Plot Protocols for 2002

Protocol	Description
Aerial Checkmate	Suterra's Checkmate sprayable pheromone, CM-F, sprayed on the walnut orchard at 20 grams/acre/application, four times per season
Aerial Isomate	Isomate's Twin Ties, CTT Ties, applied at 200 tie dispensers per acre, by air, using aerial automated pheromone dispenser
Aerial Hurcon	Hercon's Laminate, Disrupt® CM-Extra laminate, applied at 200, 2"x3" sandwich laminates per acre, using aerial automated pheromone dispenser
Isomate Mops	Isomate's Twin Ties, CTT Twin Ties, where 50 ties are placed in a plastic holder, by hand, and placed in every an average of 3.1 trees, again by hand, and using a cherry picker, for a total rate of 160 ties per acre
Isomate	Isomate's Twin Ties, CTT Twin Ties, applied at 200 ties / dispensers per acre, approximately 4 per tree, by hand, using a cherry picker
Conventional	Grower standard, where the grower treated the orchard, as needed, with conventional methods and conventional pesticide (Lorsban x 2)

As described in the proposal, appropriately timed aerial applications of pheromones, pheromone dispensers, and/or *Trichogramma* parasitoid releases have been made, as well as hand placement of two different pheromone dispensers (Isomate Mops and Isomate Twin Ties). The timing of these applications and/or releases was coordinated by Carolyn Pickel, based on data provided by the field monitoring scouts. The Principal

Principal Investigator: Russell Stocker

Investigator performed the aerial application of pheromones (Aerial Checkmate) and aerial application of Isomate and Hurcon dispensers, in addition to the *Trichogramma* parasitoid releases. All other protocols were performed by the growers or the Walnut PMA team and were ground-based applications. Table 2 provides details of the pheromone application and *Trichogramma* parasitoid release dates in each orchard. In the present growing season primarily by reducing the number of releases, the cost of *Trichogramma* releases has been reduced to \$65 per acre, including both the parasitoids and the aerial applications costs. This is a substantial reduction over previous years.

Table 2: Pheromone and *Trichogramma* Application and Release Dates for 2002

Treatment	Total Acres	County / Site	Pheromone Application	<i>Trichogramma</i> Releases
Aerial CM-F	10.3	Yuba / Yuba 2	4/8, 5/10, 6/14, and 7/26	8/7, 12, 19 and 26
Aerial Isomate	9.6	Yuba / Yuba 2	4/4	8/7, 12, 19 and 26
Isomate CTT	9.7	Yuba / Yuba 2	4/2	8/7, 12, 19 and 26
Isomate Mops	10.0	Yuba / Yuba 2	4/2	8/7, 12, 19 and 26
Aerial Hercon	10.3	Yuba / Yuba 2	4/4	8/7, 12, 19 and 26
Isomate CTT	14.9	San Joaquin / Anderson Barngrover	4/6-8	8/9, 16, 21, and 28
Isomate Mops	14.9	San Joaquin / Anderson Barngrover	4/8-10	8/9, 16, 21, and 28
Hercon	16.8	San Joaquin / Anderson Barngrover	4/8	8/9, 16, 21, and 28
Conventional	16.8	San Joaquin / Anderson Barngrover	none	none
Isomate CTT	15.6	San Joaquin / Locke	4/6-8	8/9, 16, 21, and 28
Isomate Mops	13.4	San Joaquin / Locke	4/6-8	8/9, 16, 21, and 28

Table 3: Percent Codling Moth Damage by Test Protocol - 2002

Site	Treatment	Pheromone only	Pheromone + <i>Trichogramma</i>	<i>Trichogramma</i> only	Grower standard	Control
Yuba 2	Aerial CM-F	0.4	0.4	--	1.2	1.0
Yuba 2	Aerial Isomate	1.4	1.1	--	1.2	1.0
Yuba 2	Isomate Mops	3.2	1.8	--	1.2	1.0
Yuba 2	Isomate CTT	0.4	1.8	--	1.2	1.0
Yuba 2	Aerial Hurcon	1.2	2.6	--	1.2	1.0
Andrsn/Brngrv	Isomate Mops	0.5	0.4	--	0.8	--
Andrsn/Brngrv	Isomate	0.4	0.8	--	0.8	--
Andrsn/Brngrv	Hercon	1.5	1.2	--	0.8	--
Andrsn/Brngrv	Conventional	--	--	0.7	0.8	--
Locke	Isomate Mops	2.0	2.2	--	--	--
Locke	Isomate	3.2	1.8	--	--	--

This additional year of *Trichogramma* releases has solidly reinforced the technical feasibility of placing the *Trichogramma* parasitoids in the canopy of the walnut orchards. It also has explored two alternative and exciting protocols with pheromones for mating disruption. Pacific Bicontrol Corporation, Vancouver, WA, markets the Isomate-C TT Dispensers, known as "Twin Ties", individual dispensers consisting of two plastic tubes fused together. The tubes are 7 ½ inches long, 1/8 inch ID, and enclose pheromone material, regulating its rate of release into the ambient air. In the Aerial Isomate protocol, these ties were placed in the canopy using a novel aerial dispenser. Similarly, Hurcon Environmental, Emigsville, PA, markets a "sandwich" dispenser, 2 inches x 3 inches x 1/32 inch thick, constructed of a photoprotective polymer enclosing the pheromone mixture, protecting it from premature breakdown, and regulating the rate of release into the air. These dispensers also were placed in the walnut canopy using a novel aerial dispenser. Finally, four applications of sprayable Checkmate Bend, OR, pheromone were made, by air (during the first and second codling moth generations), at 20 grams/acre. These protocols have further demonstrated that the combination of pheromone-based mating disruption in the first and second codling moth generation, followed by *Trichogramma* in third generation is a successful reduced-risk strategy for codling moth control.

B. Communicate the success of this strategy to the industry

This goal has been met. The Walnut Pest Management Alliance (PMA) Team has been proactive in refining and demonstrating pheromone mating disruption in walnuts as well as and keeping information moving from farm advisors, to field scouts, and to the end users including growers, pest control advisors (PCAs), and BIOS projects. Publication of the success of reduced risk practices is the foundation element for wide adoption. The PMA Management Team (approximately 25 individuals) continues to lead the organization and research required for adoption of these new practices. A core group of the Walnut PMA Management Team met January 24, 2002 during the Walnut Research Meeting in Bodega Bay to make decisions about the treatments to be used in the upcoming year. The Management Team met once during the season, on July 24, 2002 in Yuba City, to review and compare data collected to date and to plan field meetings or educational programs for fall 2002. The Management Team met twice in the fall to compare and analyze harvest results and to share ideas for the coming season. On October 3, the preliminary harvest results were discussed. Then, due to the high degree of complexity of pheromone-based mating disruption protocols, the team met again on November 15 to interpret and analyze the harvest results.

Field meetings and workshops are some of the ways information is extended to growers, cooperators and interested allied industry personnel. About 70 growers, PCAs and other interested parties attended a field meeting September 6 in the northern San Joaquin Valley, sponsored by the walnut PMA and addressing the ongoing activities of the Walnut PMA, including the results of a fourth year of codling moth mating disruption and the new bisexual lure for use in both conventional and mating disruption settings.

The results of this year's fieldwork were reported at the 35th Annual Walnut Research Conference in January, 2003. An update on the Walnut PMA was presented at walnut commodity meetings sponsored by farm advisors in Tehama County on February 20 and in Sutter County on February 25, 2002.

Results from the 2002 season were reported in the Walnut Research Reports, 2003 "Walnut Pest Management Alliance 2002: Year 4 Update". This report is published and made available to all walnut growers. Articles were written about the Walnut PMA in the California Walnut Commission newsletter of June 2002, entitled "Walnut PMA Concludes Year 3 with Promising Results for Sprayable Pheromone" and "IPM Project Seeks to Expand the PMA's Success with Sprayable Pheromone." The California Walnut Commission's December 2002 report was sent with a stand-alone PMA newsletter inserted. The articles detailed the goals of the PMA, codling moth damage and mating disruption, blight forecasts, and the PMA's accomplishments and lessons learned. In all, this was the most detailed newsletter yet.

Walnut PMA outreach also included the codling moth website. Researchers at the six replicated walnut PMA sites (Tehama, Butte, Yuba, and Tulare counties, and two in the northern San Joaquin region) entered their trap catch data on the University of California, Davis, IPM website. Biofixes and spray dates for each site also were entered

Principal Investigator: Russell Stocker

as the season progressed. The data is represented in graph form for each treatment block at each site, and can be viewed and downloaded by all partners and growers in the project.

4. DISCUSSION

In order for this reduced risk pest control strategy to gain acceptance with growers, it must be cost effective. For each of the test plots, the reduced risk treatment costs were similar and, for comparison, the total costs (labor, materials and equipment) for the treatments are provided in Table 4, below.

Table 4: Total Costs of All Treatments Compared to Grower Standard

Reduced Risk Treatment	Cost Per Season	
	Without <i>Trichogramma</i>	With <i>Trichogramma</i>
Checkmate Sprayable	\$184	\$249
Isomate, ties by hand	\$135	\$200
Isomate, ties by aerial dispenser	\$125	\$190
Hercon, dispensers by air	\$130	\$195
Isomate, mops by hand	\$130	\$195
<i>Trichogramma</i>	n/a	\$65
Conventional, Lorsban, 2 applications	\$86	n/a

It is important to note that costs per acre have been reduced as research has progressed in the use of *Trichogramma* as a component in alternative pest control strategies. We expect similar reductions in the cost of pheromone-based components as the use of pheromones is "fine tuned" to optimize the amount of active ingredient per acre required in each particular situation. Similarly, it is anticipated that the cost of these alternative strategies will decrease as the products become more widely accepted and utilized.

5. SUMMARY AND CONCLUSIONS

The timetable for this project has been met and the expenses are well within the budget proposed. There have been no significant problems and the principal investigator has not been prevented from meeting the objectives of the proposal or completing any of the specified tasks.

This project is demonstrating several combinations of successful alternatives to highly toxic pesticides, which reduces use of and human exposure to those pesticides while protecting surface and ground water quality. In addition, this project is a cooperative and collaborative effort between growers, the Walnut PMA, and industry, that uses a systems approach to the solution of a significant problem in the walnut industry.

6. REFERENCES

1. Pesticide Use Report, Annual 1992, Indexed by Chemical. State of California, Environmental Protection Agency, Department of Pesticide Regulation. 1992.
2. Sine C. Farm Chemicals Handbook, C. Sine, ed., Meister Publishing, Willoughby, OH, pp 32-33, 1991.
3. Varela L.G., Welter S.C., Jones V.P., Brunner J.F., Riedl H. Monitoring and characterization of insecticide resistance in codling moth (Lepidoptera: Tortricidae) in four western states. *Journal of Economic Entomology* 86:1-10, 1993.
4. Welter S.C. Pesticide resistance in codling moth: cross-resistance, resistance in field populations, and genetic selection. Research Projects for California Bartlett Pears, 1992 Report, Pear Pest Management Research Fund, Sacramento, CA, 1992.
5. Statistics of Fruits, Nut Trees and Horticultural Specialties. National Agricultural Statistics Service, 1988.
6. Integrated Pest Management for Walnuts, University of California Statewide Integrated Pest Management Project, Division of Agriculture and Natural Resources, Second Edition, M.L. Flint, ed., University of California, Oakland, CA, publication #3270, pp 36-41, 1987.
7. Maintaining the Competitive Edge in California's Walnut Industry, University of California, Agricultural Issues Center, R. Coppock (ed.), University of California Davis, 1994.
8. Vickers R.A., Rothschild G.H.L. Use of sex pheromones for control of the codling moth. In: Tortricid Pests, Elsevier, Amsterdam, pp 339-354, 1991.
9. Barnes M.M., Millar J.G., Kirsch P.A., Hawks D.C. Codling moth (Lepidoptera:Tortricidae) control by dissemination of synthetic female sex pheromone. *Journal of Economic Entomology* 85:1274-1277, 1992.
10. Webb J.E. Jr., Alden C.H. Biological control of the codling moth and the oriental fruit moth. *Journal of Economic Entomology*, 33(3):431-435, 1940.

Principal Investigator: Russell Stocker

APPENDIX

Project Summary Form, 2002

1) **Proposal Title** AERIAL RELEASE OF *TRICHOGRAMMA* TO CONTROL CODLING MOTH

2) **Principal Investigator** RUSSELL STOCKER

3) **Alternative Practices**

The use of codling moth mating disruption along with *Trichogramma* was used to replace the use of conventional pesticides.

4) **Summary of Project Successes**

This project is demonstrating several combinations of successful alternatives to highly toxic pesticides, which reduces use of and human exposure to those pesticides while protecting surface and ground water quality. In addition, this project is a cooperative and collaborative effort between growers, the Walnut PMA, and industry that uses a systems approach to the solution of a significant problem in the walnut industry.

5) Number of participating growers	9	12) Number of Field Days	1
6) Total Acreage in Project	340	13) Attendance at Field Days	70
7) Project Acres Under Reduced Risk	327	14) Number of Workshops & Meetings	6
8) Total Acres of Project Crop	Unknown	15) Workshop Attendance	315
9) Non-Project Reduced Risk Acres	Unknown	16) Number of Newsletters	2
10) Number of Participating PCAs	9	17) Number of Articles	4
		18) Number of Presentations	3

11) Cost Assessment

Reduced Risk Treatment	Cost Per Season	
	Without <i>Trichogramma</i>	With <i>Trichogramma</i>
Checkmate Sprayable	\$184	\$249
Isomate, ties by hand	\$135	\$200
Isomate, ties by aerial dispenser	\$125	\$190
Hercon, dispensers by air	\$130	\$195
Isomate, mops by hand	\$130	\$195
<i>Trichogramma</i>	n/a	\$65
Conventional, Lorsban, 2 applications	\$86	n/a

19) Other Outreach Activities None

FOR OFFICIAL USE ONLY	Contract Number	Project ID
DPR ID#	Contract Manager	25th June 2001 Version