THE PROJECT NARRATIVE

Title: Biological Control of Navel Orangeworms Attacking Almonds

Justification: Lepidopterous pests of perennial crops have historically posed serious threats in California to orchards and vineyards. Among the most serious is the navel orangeworm, Amyelois transitella (Walker). Population densities of the navel orangeworm have been on the increase in almond groves, where the estimated 1978 crops loss to this pest exceeds 30 million dollars. Orangeworm is also being incriminated with the production of carcinogenic compounds in almonds, so that its threat to the industry is potentially greater.

Navel Orangeworm (Amyelois transitella).--Following its invasion of California around 1942, this pest became an increasing threat to the walnut and almond industries. A program to introduce natural enemies was initiated in 1962. The parasite Phanerotoma flavitestacea Fisher was introduced from a related host Ectomyelois ceratoniae (Zell.) in Israel (Gothilf 1968, 1969a & 1969b). This was followed by the importation of several strains of the polyembryonic parasite Pentalitomastix plethoricus from Mexico. Pentalitomastix is presently being stressed for biological control of navel orangeworm in almonds and walnut although no satisfactory drop in pest density has been recorded. A virus disease found in northern Mexico appears promising. Other key references are Caltagirone (1963, 1971, 1975), Caltagirone et al. (1964), Ebeling (1950), Summers (1972), Summers & Price (1974), and Wade (1961).

The search for additional natural enemies over a broader range of this pest in Central and South America, especially in climatic zones similar to California's Central Valley, is a logical extension of the biological control effort.

Procedure: Established experimental or investigative techniques will generally be followed in the proposed investigation. Natural enemy-host population dynamics studies will be undertaken in the laboratory and field. Techniques for sampling natural enemy and host populations are already developed. In order to measure the effectiveness of a natural enemy in regulating the population density of its host, experimental comparisons will be made between orchards and vineyards, portions thereof that have natural enemies operating under natural conditions and plots that do not have natural enemies present (excluded or greatly reduced experimentally) as described in the following outline:

(1) Population Ecology

Seasonal succession of parasites and predators will be followed by recording species abundance in fruit or on leaf samples. This will be related to weekly weather conditions which are to be instrumentally recorded. Comparisons will be made of findings from orchards and vineyards in different portions of California. Introduced natural

enemies that have been released from quarantine will be liberated in all environments and their establishment on the host population recorded. Several orchards and vineyards have already been chosen for these studies where cooperation with the owners allows for the optimum conditions.

(2) Biology of Parasites and Predators

Facilities available through collaboration with growers permit typical and completely manageable experimental conditions. Laboratory studies will be made at the University of California, Riverside, to determine factors influencing host selection and parasite searching ability. Continuous culture of parasites will be made available by laboratory helpers and research assistants.

(3) Improved methods of assaying natural parasite activity and the capture of parasites and predators have been developed by earlier projects at the university, so that extended searches for natural enemies will be more efficient. Areas to be surveyed for natural enemy activity will eventually include portions of South and Central America, the Middle East and Eurasia. In some parts of the world where the key lepidopterous pests in question were though to have originated they are not as abundant as in California, which could be due to a higher degree of established natural control.

(4) Genetics

a. Attempts will be made to artificially improve strains of parasites and predators. This involves subjecting populations to extreme conditions and then culturing the survivors and repeating the process until desirable results are obtained. Parthenogenetic females may be isolated from cultured species by separating individual virgin females in large scale replications and checking for production of female progeny. Virgin females of biparental species normally produce males only (Flanders 1949, DeBach 1958a, 1958b). This would be an excellent means of "fixing" any desirable modifications achieved by selective breeding.

b. The environmental stimuli necessary to cause a virgin female hymenopteron to produce bisexual progeny will be studied in an effort to regulate the process to our advantage. It is known that high temperatures, periods of starvation and other external phenomena are involved, although the extent of any remains unsolved.

c. Another technique with potential for improving parasites for maximum field performance is directed positive heterosis (Hoy 1976, Legner 1972), where geographically isolated strains of the same species are deliberately crossed to obtain the desired effect.

(5) Taxonomy

The distinction of parasitic strains with biological characteristics will be effected primarily by (1) their ability to parasitize a

standard host infestation in laboratory cages, (2) their length of development at comparable temperatures and humidity, and (3) their respective longevity and fecundity. Other valid separating traits will be used as they are discovered.

(6) Sampling

Standard procedures for sampling each respective species will be used. Simplified methods of processing and incubation will be developed. New methods of sampling may be tested according to empirical models prescribed by biometricians at the University of California.

(7) Biological Control

Introductions of parasites, predators and diseases having the greatest potential in their native home will be made to California in biological control attempts. Host eggs, larvae and pupae will be sampled periodically preceding and following natural enemy releases. Samples will be designed to measure directional movements of parasites and ranges of dispersal. Portions of experimental areas will be variously treated with kairomones, watering stations, or cultured in other ways in efforts to favor natural enemy activity. Wild walnut reservoirs will be closely watched for the establishment of natural enemies, as they are less disturbed, often bear heavy pest infestations and should show adaptation by natural enemies more quickly than in commercial situations.

Because the different species of hymenopterous and dipterous parasites that attack host eggs, larvae and pupae have partially or wholly identical ecological niches, we will have an opportunity to study the Competitive Exclusion Principle of Hardin (1960) and Competitive Displacement (DeBach 1974). Laboratory studies of competition between parasite species will be made in screened plastic cages in an insectary. By subjecting series of these cages to different conditions the effects of temperature, light and other factors on the results of competition can be measured and analyzed.

Information on the multiplication of parasites and predators in the field at different times of the year and under varying cultural manipulations of the breeding media will be useful to direct their most efficient employment in biological control.

Facilities: At our disposal are the manual assistance of maintenance staff, space and machinery of the Agricultural Experiment Station. Several controlled temperature and humidity rooms are available for culture and test work in the Division of Biological Control. All rooms are equipped with water, vacuum, compressed air and carbon dioxide outlets. Specially designed screened plastic cages for studies on competition between species of parasites are on hand. Adequate microscopic and photomicroscopic equipment are assigned to the project leader. Addi-

tional assistance is available from cooperative growers in the Central Valley of California. The Division of Biological Control is also in a unique position to be able to introduce living beneficial organisms directly from outside the continental limits of the United States through facilities available in a specially designed quarantine wing of the insectary. It is the only one of two state agencies in the United States which enjoys this privilege.

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Navel Orangeworm Research
(Biological Control)

Equipment	-0-
Supplies & Expense	
Supplies related to the culture of navel orangeworm and its parasites; shipment of media to collaborators; air freight charges.	$ 3,280
Travel	
Domestic:	
Portions of the Southwest from Arizona through Texas 2 MM at 20 md/mo at $40/day Per diem.	$ 1,600
Vehicle Rental (3 months)	270
10,000 miles at 13.5/cents/mi Mileage	1,350
Total Domestic Travel	$ 3,220
Other	
Collaborators' fees for the search and procurement of natural enemies of the navel orangeworm.	
South America (A. Silveira-Guido)	8,000
Greece (L. Argyriou)	1,500
Total Collaborator Fees	9,500
GRAND TOTAL	$16,000

Navel Orangeworm Natural Enemy

Quarantine Report

(November 27, 1978)

S&R No.	Host Plant	Locality	Collection Date	Emergence
78-27				
1	walnut	Ft. Davis, Tex	8 July	none
2	acacia	N.E. Big Bend	9 July	none
3	acacia	S.E. Big Bend	9 July	none
4	cat's claw	Big Bend Nat. Park	9 July	none
5	cat's claw	N. Big Bend	9 July	none
6	Acacia farnesciana	Rio Grande Ranger Sta.	9 July	none
7	chinaberry	Old Dime Box	9 July	none
8	Sapindus	Kingsville, Cemetery	10 July	1 orangeworm 100+ ♂ Pentalitomast
9	Texas ebony	Kingsville, Cemetery	11 July	51 Horismenus 15 Trichogramm
10	Texas ebony	Kingsville Ranch Hdqs.	12 July	1 ♂ spider
11	Acacia farnesciana	McAllen, Tex.	12 July	2 Chelonus sp.
12	Chinaberry	Corpus Christi	12 July	none
13	Chinaberry	Mesquite (nr. Dallas)	13 July	none
14	Chinaberry	Arlington (cemetery) (nr. Dallas)	14 July	none
78-29				
1	almonds	Toquerville, Utah	29 Aug.	none
2	walnuts	Toquerville, Utah	29 Aug.	none
3	almonds	Hurricane, Utah	29 Aug.	none
4	walnuts	Torquerville, Utah	29 Aug.	none
5	almonds	Hurricane, Utah	29 Aug.	none
6	pecans	Hurricane, Utah	29 Aug.	none
7	almonds	Toquerville, Utah	29 Aug.	20 ♂ Pentalito· mastix
8	almonds	Hurricane, Utah	30 Aug.	none

S&R No.	Host Plant	Locality	Collection Date	Emergence
78-30				
1	Sapindus	Alpine, Tex.	30 Aug.	none
2	Sapindus	Rattlesnake Spr., Carlsbad, N. Mex.	28 Aug.	none
3	Juglans	Rattlesnake Spr., Carlsbad, N. Mex.	28 Aug.	Husk fly pupa
4	Juglans	Walnut Canyon Carlsbad, N. Mex.	28 Aug.	Husk fly pupa
5	Juglans	2 mi. S. Alpine, Tex.	30 Aug.	Husk fly pupa
6	Juglans	Parkline, Tex.	30 Aug.	Husk fly pupa
7	Green Sapindus	Rattlesnake Spr., N. Mex.	28 Aug.	none
8	Juglans	1.6 mi. N. Observatory, June.	29 Aug.	Husk fly pupa
9	Juglans	10 mi. N. Alpine, Tex.	30 Aug.	Husk fly pupa
10	Juglans	Davis Mt. State Park	30 Aug.	Husk fly pupa
11	Juglans	Davis Mt. State Park (canyon)	29 Aug.	Husk fly pupa
12	Acacia farnesiana	Boquillus, Tex.	30 Aug.	1 Chelinus sp. many weevils
13	Juglans	2 mi. N.W. Ft. Davis, Tex.	29 Aug.	Husk fly pupa
14	Juglans	Indian Lodge, Tex.	29 Aug.	Husk fly pupa
15	Juglans	N.E. Davis Mts., Tex.	29 Aug	Husk fly pupa
78-33				
1	Sapindus	Rattlesnake Spr. N. Mex.	24 Sept.	none
2	Sapindus	Alpine, Tex.	25 Sept.	none
3	Sapindus	Marathon, Tex.	25 Sept.	none
4	Mexican persimmon	Big Bend, Tex.	25 Sept.	none
5	Acacia farnesiana	Boquillus, Tex.	25 Sept.	1 ♀ Braconid 20 Horismenus
6	Sapindus	Kingsville, Tex.	27 Sept.	none
7	Texas ebony	Kingsville, Tex.	27 Sept.	260♀&♂ Penteitomastix Horismenus many weevils 1 Navel Orang worm
8	Texas ebony 3 mi. S. Alice, Tex.	Corpus Christi, Tex.	27 Sept.	weevils 8 Goniozus emigrata
9	Acacia farnesciana	Corpus Christi, Tex.	27 Sept.	none

S&R No.	Host Plant	Locality	Collection Date	Emergence
78-40				
1	Texas ebony	2 mi. S. Alice, Tex.	6 Nov.	weevils 3 Braconids
2	Texas ebony	3 mi. S. Alice, Tex.	6 Nov.	1 Horismenus 4 Braconids 32 Pentalitomastix 1 Navel orangeworm
3	Texas ebony	Junc. Hwy 141 Santa Bertrudis-Kingsville	6 Nov.	6 Horismenus 2 Braconids 1 Eulophid weevils
4	Texas ebony	Entrance-Kings Ranch	6 Nov.	12 Horismenus 1 Eulophid 53 Pentalitomastix 2 Navel Orange worm weevils
5	Texas ebony	1/2 mi. W. Kings Ranch	6 Nov.	200+Pentalitomastix 7 Horismenus 2 Navel orange worm 2 Braconids weevils
6	Sapindus	Kingsville Cemetery	7 Nov.	none
7	Texas ebony	620 W. Richard Ave., Kingsville, Tex.	7 Nov.	2 weevils
8	Chinaberry	300 N. 10th St., Kingsville	7 Nov.	none
9	Texas ebony	Riviera, Tex.	7 Nov.	1 Hymenoptera
10	Texas ebony	4 mi. E. Riviera, Tex.-Kings Inn	7 Nov.	2 Navel orangeworm 35♂ Pentalitomastix
11	Texas ebony	1702 Santa Gertrudis-Kingsville	8 Nov.	1♀ Bethylid
12	Texas ebony	Riviera, Tex.-Mesquite Inn	8 Nov.	none
13	Texas ebony	Richard & Univ.-Kingsville	8 Nov.	none
14	Texas ebony	Robstown, Tex.	8 Nov.	none
15	Texas ebony	Taft, Tex.	8 Nov.	none

RIVERSIDE: OFFICE OF
DEAN, COLLEGE OF NATURAL
AND AGRICULTURAL SCIENCES
ASSOCIATE DIRECTOR,
CITRUS RESEARCH CENTER AND
AGRICULTURAL EXPERIMENT STAT

December 22, 1978

TO: WARREN C. MICKE
Extension Pomologist
(Almond Liaison Officer)

Enclosed is a proposal to the Almond Control Board from E. F. Legner, entitled Field Release and Establishment of New Natural Enemies of Navel Orangeworm, along with the commodity data form.

Lowell N. Lewis
Associate Dean of Research

Enclosures

UNIVERSITY OF CALIFORNIA
OFFICE OF THE VICE PRESIDENT--
AGRICULTURE & UNIVERSITY SERVICES

(Continuation of Project No. 78-F5)

Data for Projects Supported by Commodity Groups and Federal & State Marketing Orders

Agricultural Experiment Station or Cooperative Extension Project No. 3519

Marketing Order Almond Control Board

UC Department or Unit Address Division of Biological Control, University of California, Riverside 92521

Project Leader E. F. Legner Telephone (714) 787-5709

Other Personnel Involved R. A. Medved (Staff Research Associate IV)

Project Title Field Release and Establishment of New Natural Enemies of Navel Orangeworm

Objectives (brief): To effect the field release and establishment of new natural enemies of the navel orangeworm in the Central Valley of California--companion project to previously submitted proposal to acquire new natural enemies from the native range of navel orangeworm in America.

Progress & Plans (for ongoing projects – give a brief current status report and plans for the coming year):

(Same as previously submitted proposal)

Budget Request: Salaries – Details

Total Salaries	$2,044	
Employee Benefits	38	
Supplies & Expense	807	
Equipment	-0-	
Travel	3,989	
	Total	$6,878

Reviewed by:

Department Chairman R. B. March,

Cooperative Extension Assistant Director _____
(For Cooperative Extension Projects)

Liaison Officer _____

5/78

THE PROJECT NARRATIVE

Title: Field Release and Establishment of New Natural Enemies of Navel Orangeworm

The project is similar to that submitted in our first proposal, except that the additional budget enables mass production and intensified field releases of natural enemies acquired.

Procedure: Natural enemies that are acquired during the foreign exploration phase of this work will be mass produced and field released in the Central Valley of California from Chico to Wasco. Almond groves where chemical control is limited to peach twig borer and mites early in spring (no sprays after May) will be selected for natural enemy establishment. In our previous agreement this phase of the control was to be carried out by the Division of Biological Control, Berkeley. However, we have been informed that Berkeley will not submit a proposal for 1979. In this case, we would be required to maintain living cultures of parasites for at least 1 year before field releases are attempted on a staisfactory scale. Not only is genetic material in danger of being lost (eg. aggressiveness, host-searching capacity, fecundity, etc.), but the time required to maintain the 4 species presently in our possession would greatly restrict our attention to new material that arrives from South American and the southwestern USA. Indeed, 3 cultures of egg-attacking Chelonus spp. might have to be eliminated as maintenance costs alone prohibit their perpetuation. Furthermore, if any of the parasitic species currently in our possession are capable of lowering the pest status of navel orangeworm, such control would be delayed by at least one year.

The species now being cultured on navel orangeworm are larva-attacking Goniozus emigrata (Bethylidae) collected from Amyelois transitella at Alice, Texas, and egg-attacking Chelonus blackburni (Braconidae) with origins in NE Australia attacking Pectinophora scutigera on tree-like hibiscus; Chelonus sp. from Ethiopia and Chelonus sp. from NW Australia attacking Pectinophora gossypiella in commercial cotton as well as in native small tree-like hibiscus species. The latter 3 species have been used with some effectiveness in low desert areas against the pink bollworm. However, basic studies have shown their intense response to chemical cues (kairomones) emitted by Amyelois transitella. Although annual releases of these parasites are required for control in cotton, the comparative greater stability of the almond orchard environment, and the continuous year-round availability of A. transitella may permit their permanent establishment and significant perpetual impact against Amyelois.

It is imperative that this project begin April 1st, 1979, as the critical parasite-release period will be April-July. A July 1st beginning will produce little information (if any) about these parasites' usefulness in 1979. Cultures of all parasites would have to be continued for at least one year, with the aforementioned burden on our financial resources and the threat of gene loss.

Navel Orangeworm Research
(Biological Control)

Proposal II

Salaries		
Laboratory Helper 50% time 4/1/79 - 9/30/79 @ $3.93/hr		$ 2,044
	Total Salaries	2,044
Employee Benefits		
Laboratory Helper, 1.85% of $2,044		38
	Total Employee Benefits	38
Equipment		-0-
Supplies & Expense		
Supplies related to the mass culture of navel orangeworm and its parasites--glyceron 1.25 gal/mo ($475); vitamins ($45); honey 20 lb/mo ($200); sugar 50 lb/yr ($12); Bran mix 600 lb per yr ($50); yeast ($25)		807
Travel		
Domestic		
Riverside-Wasco-Chico-Riverside 5 MM at 10 md/mo at $40/day Per diem		2,000
Vehicle rent (additional 2 months)		180
2 trips/mo April-Aug = 10 trips; at 1300 miles each = 13,400 miles @ 13.5/cents/mi Mileage		1,809
	Total Domestic Travel	3,989
	GRAND TOTAL	$6,878

UNIVERSITY OF CALIFORNIA
OFFICE OF THE VICE PRESIDENT--
AGRICULTURE & UNIVERSITY SERVICES

(Continuation of Project No. 78-15)

78-F

Data for Projects Supported by Commodity Groups and Federal & State Marketing Orders

RECEIVED
JAN 5 1978

Agricultural Experiment Station or Cooperative Extension Project No. 3519

keting Order

UC Department or Unit Address Division of Biological Control, University of California, Riverside 92521

Project Leader E. F. Legner Telephone (714) 787-5709

Other Personnel Involved R. A. Medved (Staff Research Associate IV)

Project Title Navel Orangeworm Research (Biological Control)

Objectives (brief): To control navel orangeworm by means of new natural enemies--parasites and predators--so as to reduce as much as possible its economic importance as a pest.

Progress & Plans (for ongoing projects – give a brief current status report and plans for the coming year):

Exploration for new natural enemies of the navel orangeworm during 1978 extended to key portions of Uruguay and Argentina, East and West Texas, Utah and Arizona. (See attachment #1). Living cultures of two species, Goniozus emigrata and Pentalitomistix plethoricus were secured from central and south Texas and are currently in the process of mass production. Dead specimens of emerged parasites from carob moth collected in Greece and from carob moth and relatives of navel orangeworm in Uruguay and Argentina are being identified, with living collections intended for 1979.

Future plans are to intensify collections of parasites in the above areas and to begin field releases of new parasitic species and strain in Central California.

Budget Request: Salaries – Details

Total Salaries --none
Employee Benefits --none
Supplies & Expense --$3,280
Equipment --none
Travel -- $3,220
Collaborators -- $9,500 Total $16,000

Reviewed by:

Department Chairman

Cooperative Extension Assistant Director
(For Cooperative Extension Projects)

Liaison Officer

6/78