CALIFORNIA OLIVE COMMITTEE

SUBCOMMITEE ON RESEARCH

2013 PROPOSALS

PROJECT LEADER	PROPOSAL	COST
Jim Stewart	Southern San JoaquinValley Olive Fruit Fly Monitoring Project	$6,200
Dr. Carol Lovatt and Dr. Elisabeth Fichtner	Alternate Bearing in Olive	$39,213
Dr. Louise Ferguson	Improving Mechanical Harvesting Efficiency with Engineering and Pruning	$91,478
Dr. Louise Ferguson	Propagating Dwarfing Olive Rootstocks and Establishing a Long Term Orchard	$17,205
Dr. Jim Adaskaveg	Epidemiology and management of olive knot caused by *Pseudomonas syringae* pv. *savastanoi*	$64,000

PROJECT PLAN/RESEARCH GRANT PROPOSAL

Project year: 2013 Anticipated Duration of the project: April –November 2013

Project Leader: Jim Stewart Location: Tulare County
Mailing Address: PO Box 1095, Exeter CA 93221
Phone: (559) 730-6243 FAX: (559) 592-4105 E-mail: jsagipmc@verizon.net

Project Title: Southern San Joaquin Valley Olive Fruit Fly Monitoring Project

Cooperating personnel: Bert Quezada

Keywords: Olive Fruit Fly, Monitoring, Traps,
Commodity: Olive

PROBLEM AND ITS SIGNIFICANCE:

The monitoring of Olive Fruit Fly (OLFF) in commercial olive groves in the Southern San Joaquin Valley started in 2001. OLFF is potentially the most significant insect pest in commercial Olive.

OBJECTIVES:

The objective of this project would be to continue the monitoring program of adult OLFF in commercial olive groves in the Southern San Joaquin Valley. Detection and seasonal monitoring of OLFF and the accurate timing of control measures, primarily bait sprays, would be the goal of this project. Correlation of fly collections with fruit susceptibility to infestation would indicate to growers when initial bait treatments should be applied. In addition, monitoring would continue to give growers information on the general OLFF population. This information would specific for only the groves being monitored and would be available to growers to aid in making OLFF management decisions in their respective groves in the area being trapped.

PLANS AND PROCEEDURES:

The same nine sites used in the years 2007 to 2012 in commercial olive groves will be set up with traps in April of 2013. The locations will be Ivanhoe, Woodlake, Exeter, South Exeter, Tonyville, West Lindsay, Strathmore, Porterville and Terra Bella. In addition, a site in the city of Visalia would also be monitored. All of these sites are in Tulare County where a high percent of the commercial olives are located in the Southern San Joaquin Valley. Some of the sites have been monitored starting in 2001. All traps will be in place by the first week of April and the program will end the last week of November. Two yellow panel traps with ammonium carbonate bait and male pheromone will be used per site. Traps will be serviced and OLFF counted weekly. Reports detailing the number of OLFF found at each location would be submitted to the California Olive Committee and interested parties within 24 hours on a weekly basis.

BUDGET REQUEST

Budget year: April 1, 2012-December 1, 2012

Funding Source: California Olive Committee
Leffingwell Ag Sales Co., Inc.
Ag IPM Consultants, Inc.

Salaries and benefits:	$15,000.00
Supplies:	
Traps, bait and pheromone	1200.00
Travel:	
Mileage to trap sites	2,400.00
Equipment:	0.00
TOTAL	$18,600.00

Funding would be split equally between the above listed funding sources.

Total funding from the California Olive Committee would be: $6,200.00

James R. Stewart
Project leader
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Olive Workgroup / Department of
Botany and Plant Sciences, UCR

University of California
Division of Agricultural Sciences

PROJECT PLAN/RESEARCH GRANT PROPOSAL

Project Year: 2013

Anticipated Duration of Project: 2 years in order to determine the effect of treatments applied in late spring-early summer 2013 and spring 2014 on return bloom and vegetative shoot growth in spring 2014. Treatments include fruit removal from whole trees and PGRs. Thus, the Year 2 budget will likely be less than the Year 1 budget.

<u>Project Leaders</u>: Carol Lovatt and Elizabeth Fichtner

Project Leaders' Contact Information:
CL-Professor of Plant Physiology, Botany and Plant Sciences-072, UC-Riverside, CA 92521-0124 Phone: 951-827-4663; Fax: 951-827-4437; Email: carol.lovatt@ucr.edu

EF-Farm Advisor, Orchard Systems, Cooperative Extension, 4437 S. Laspina St., Tulare, CA 93274, Phone: 559-684-3310; Fax: 559-685-3319; Email: ejfichtner@ucdavis.edu

Location: Commercial table olive orchard(s) in Tulare County

<u>Project Title:</u> Alternate Bearing in Olive - *Determining when fruit exert their negative effect on return bloom, whether the effect includes inhibition of floral development or only inhibition of bud break, and refining PGR treatments to break AB ON/OFF cycles*

Cooperating Personnel:
<u>Clarence Hill</u> Commercial table olive grower, Exeter
Lindcove Research and Education Center, Exeter

Keywords: Alternate bearing, ON-crop trees/year, OFF-crop trees/year, correlative inhibition, vegetative shoot extension growth, bud break, staminate flowers, perfect flowers, inhibition of floral development, plant growth regulators, fruit removal

Commodity(s): Table Olive Relevant AES/CE Project No.: 4556H

<u>Problem and its Significance:</u> Alternate bearing (AB), production of a heavy "on-crop" (high yield, ON trees) followed by a light “off-crop” (low yield, OFF trees), occurs in perennial fruit and nut crops and in forest species (where it is called “masting”). AB is a serious problem of significant economic consequence to table olive growers, and probably oil olive growers (Sibbett 2000). Industry-wide, yield can vary from 46,300 tons one year to 195,000 tons the next (USDA NASS 2011 CA Olive Probability Survey Report). In ON years, trees produce a large number of small size fruit with reduced commercial value. In OFF years, trees produce large fruit but too few to provide a good income to the grower. For olive, the ON-crop takes longer to mature, attain size and accumulate oil. The delayed harvest further exacerbates AB.

<u>There is a recurring need to mitigate the problem of alternate bearing.</u> Alternate bearing is initiated by external factors (freeze; lack of chilling; low or high temperatures at bloom, pollination or fruit set; diseases etc) that cause poor flowering or pollination or excessive flower and fruit drop, resulting in an OFF-crop that is typically followed by an ON-crop, depending on how long it takes the trees to recover from the stress causing the loss of yield. Conversely, optimal conditions during bloom and fruit set such that crop thinning fails to take place result in an ON-crop, which is followed by an OFF-crop. Since climate is a factor initiating AB, the need for a corrective strategy reoccurs.

Results from our last research project. The goal of our previous research was to determine whether the mechanisms perpetuating the repeating ON- and OFF-crop cycles in 'Pixie' mandarin applied to olive. Here we summarize the five hypotheses we tested on olive and the results.

HYPOTHESIS 1: The ON-crop of olive fruit reduces return bloom in olive by inhibiting bud break for summer vegetative shoot extension growth in Year 1 (2011), thereby reducing the number of nodes that can produce inflorescences the next spring. **This hypothesis is true for olive.** The results in Table 1 (below) provide clear evidence that fruit inhibit summer vegetative shoot extension growth. The results provide evidence that the greatest growth was attained by mid-July by shoots that did not set fruit on OFF-crop trees (OFF/-fruit). These shoots grew more than shoots that did not set fruit on ON-crop trees (ON/-fruit), revealing the strong whole tree inhibitory effect of the ON-crop compared to the OFF-crop. Shoots that set fruit on ON-crop trees (ON/+fruit) produced the least amount of new growth, demonstrating the localized effect of the individual fruit set on the shoot combined with the whole tree effect of the ON-crop. Additional preliminary results of our study removing fruit from shoots of ON- and OFF-crop trees indicated that removing fruit in June increased summer vegetative shoot extension growth from June to September to a greater degree than removing fruit at a later date (even July), suggesting that the effect of fruit on summer shoot extension growth occurs *before* July. In our proposed research, we will determine how early in the season the setting fruit (possibly the inflorescences) inhibit vegetative shoot extension growth.

HYPOTHESIS 2: The ON-crop of olive fruit reduces return bloom by inhibiting bud break for summer vegetative shoot extension growth in Year 1 by increasing the auxin to cytokinin ratio in the apical bud that produces the new growth. This phenomenon is known as correlative inhibition If true for olive, treating trees with an auxin-tansport inhibitor and/or a cytokinin will overcome the inhibition of bud break and increase shoot growth. In Table 2 (Parts A and B), it is clear that injecting the auxin-transport inhibitors tri-iodobenzoic acid (TIBA) and naringenin (NAR, a natural product) with or without the cytokinin 6-benzyladenine (BA) or the proprietary cytokinin (CPK, a natural product) increased summer vegetative shoot extension growth on ON-crop trees (i) for shoots without fruit (Table 2 Part A) and (ii) shoots with fruit (Table 2 Part B) relative to the equivalent shoots of untreated ON-crop control trees (ON/-fruit and ON/+fruit) and equal to untreated OFF-crop control trees (OFF/-fruit). See the treatments marked with an asterisk. **This hypothesis is true for olive.** In spring of project year 2013, half the trees treated with PGRs in summer 2012 will receive a second PGR treatment to increase spring bud break. The results will tell us if combining the summer and spring treatments increased floral intensity following the ON-crop year to a greater degree than just treating the trees in summer or spring only.

HYPOTHESIS 3: The ON-crop in Year 1 (2011) reduces the floral intensity of the return bloom in olive in Year 2 (2012). The results in Table 3 provide clear evidence that **this hypothesis is true.** Shoots that did not set fruit on OFF-crop trees in 2011 (OFF/-fruit) produced the most inflorescences in 2012. ***Note:*** In Table 3, shoots that produced many inflorescences concomitantly produced less vegetative shoot extension growth (new nodes) from bud break (BB) through May, resulting in few nodes to bear inflorescences in Year 3. Shoots that did not set fruit on ON-crop trees in 2011 (ON/-fruit) also produced many floral shoots in 2012, but shoots of ON-crop trees that set fruit in 2011 (ON/+fruit) produced few inflorescences. ***Note:*** In Table 3, independent of the number of inflorescences produced per shoot of ON-crop trees the following spring, vegetative shoot extension growth from bud break to May was significantly greater than that of the 2011 OFF-crop trees that produced an intense bloom in spring 2012. For the 2011 ON-crop trees, the low number of inflorescences will result in an OFF-crop in 2012, but the high number of new nodes produced in spring 2012 will result in an ON-crop again in 2013 (Year 3). Thus, the number of new nodes produced during the spring of the ON-crop year is a key determinant of floral intensity the following spring. In our new project, we will determine more precisely when the setting crop (or even inflorescences) exerts a negative effect on vegetative shoot extension growth.

There is another important piece of information derived from these results. At bloom following the ON-crop year, it is clear that the shoots that *did not set fruit* on ON-crop trees are the ones producing the majority of inflorescences the following year. The problem is there are too few shoots without fruit on ON-crop trees to achieve a good bloom following the ON-crop. Thus, we must develop a strategy to increase floral intensity on shoots that set fruit on the ON-crop trees. However, at this time, we do not know whether the reduced number of inflorescences on shoots that set fruit on ON-crop trees (ON/+fruit) is due to inhibition of bud break only or inhibition of floral development and, if the case, when the triggering event occurs. In project year 2013, we will answer these questions. We have a partial answer already (see below).

HYPOTHESIS 4: For shoots without fruit on ON-crop trees, bud break, not floral development, is inhibited. If this hypothesis is true, plant growth regulators known to increase bud break in spring will increase floral intensity at return bloom. **This hypothesis is true for olive.** The results in Table 4 (Part A) demonstrate that both cytokinins (BA and PCK) increased the number of inflorescences produced by shoots that did not set fruit on ON-crop trees (ON/-fruit) to a value greater than shoots without fruit on OFF-crop trees (OFF/-fruit). See the treatments marked with an asterisk in Table 4 Part A. In addition, we are also very interested in the PGR treatments (marked with daggers) that increased inflorescence number to a value equal to that of shoots without fruit on OFF-crop control trees (OFF/-fruit) and also increased the number of new nodes from bud break to May to a value similar or equal to the ON-crop control trees, because these are the nodes that will bear inflorescences in Year 3. In our proposed project, we will determine whether treatments that increase bloom in spring and also increase the number of new nodes on vegetative shoots by May go on to produce a large number of inflorescences again the following year, i.e., two ON blooms in a row.

HYPOTHESIS 5: For shoots with fruit on ON-crop trees, failure of PGRs known to stimulate spring bud break to increase inflorescences number following the ON-crop year leaves open two possibilities: (i) the buds are more deeply inhibited but remain viable floral buds or (ii) floral development is inhibited and the buds are no longer viable floral buds. Treating trees with PCK or TIBA plus PCK in February or TIBA plus BA in March increased inflorescence number more than 6-fold over the untreated ON/+fruit control, but the increase was not significant at the 5% level. Moreover, inflorescence number remained 3-fold lower than the OFF/-fruit control. See treatments marked with an asterisk in Table 4 Part B. These results leave open both possibilities posed above. In project year 2014, we will be able determine whether bud break of buds of shoots +fruit on ON-crop trees are simply inhibited (viable) or whether floral development was inhibited (not viable floral buds). The answer to this question is critical for evaluating and improving the efficacy of PGR or flower and fruit thinning treatments to mitigate AB.

A model illustrating the cycling of ON- and OFF-crops in 'Manzanillo' olive trees. The reciprocity between floral shoot and vegetative shoot development (Tables 3 and 4) results in the annual cycling of ON- and OFF-crops in olive during alternate bearing (Fig. 1).

Objectives: (1) to determine more precisely when the ON-crop of fruit exerts its negative effect on vegetative shoot extension growth and on return bloom; (2) to determine for shoots bearing fruit whether this effect includes inhibition of floral development or only inhibition of bud break; and (3) to test the ability PGR treatments to break the AB cycles by increasing floral intensity or both floral intensity and vegetative shoot length (node number) the year following the ON-crop to produce high back to back yields.

Plans and Procedures: To meet Objective 1, we will remove the ON-crop (possibly even the ON bloom) from 'Manzanillo' olive trees (70% of the California table olive industry) (http://www.ipmcenters.org/pmsp/pdf/CAOLIVEPMSP.pdf), located at the Lindcove REC in Exeter, CA, monthly from May to harvest in October. We will quantify the effect of time of fruit removal on vegetative shoot growth and the number of inflorescences produced at return bloom to identify when the ON-crop of fruit is exerting its effect on bud break, floral development, and vegetative shoot development at the level of the whole tree. To meet Objective 2, in spring, half the trees with their fruit removed in the experiment above will be injected with the PGR treatment/s that most effectively increase/s inflorescence number (identified from our prior research results) in order to determine if buds are merely inhibited from undergoing bud break and remain viable or are not viable floral buds due to inhibition of floral development. We will collect buds in spring. If the results of our fieldwork are not clear, we will analyze bud anatomy by microscopy or bud floral gene expression to meet this objective. Knowing the viability of buds on shoots that set fruit on ON-crop trees is critical to understanding the potential of PGRs or crop thinning (by chemical or by hand) to increase return bloom and also to determine by when these treatments must be carried out to be effective. To meet Objective 3, we will test the ability of PGR treatments that increased inflorescence number following the ON-crop year (Table 4 Parts A and B, treatments marked with an asterisk). We will also test those PGRS that increased inflorescence number to a lesser degree but also increased shoot growth (node number) following the ON-crop year (Table 4 Parts A and B, treatments marked with a dagger). The goal is to produce strong blooms and good yields back to back.

NOTES: Naringenin and the proprietary cytokinin are natural products, which should make registration less expensive and faster than registering plant growth regulators, which are classified as pesticides. Trunk injections are used to test the concept because trunk injected compounds are not compromised by poor leaf uptake, making the results of the treatment clear. If the concept is correct, foliar sprays will be developed and their capacity to increase return bloom and yield tested under a subsequent proposal, at which time problems related to foliar uptake will be resolved.

All treatments, including the ON- and OFF-crop control trees, will be replicated on 7 individual trees (replications) in a randomized complete block design. Together, the 2012 bloom data compared to data to be obtained in spring 2013 will indicate whether an auxin-transport inhibitor plus a cytokinin are required to increase floral intensity following the ON-crop or whether an auxin-transport inhibitor alone or a cytokinin alone is sufficient. The results obtained in 2013 will also establish whether a PGR treatment in spring is sufficient or whether an earlier treatment in summer provides an added benefit for increasing return bloom intensity.

At bloom in 2013 and 2014, we will quantify the number of floral shoots on five shoots with and without fruit on untreated ON- and OFF-crop control trees and treated trees (fruit removed or PGRSs injected) at the Lindcove REC. This current year we paid to have fruit removed from trees during the summer and we paid to have the remaining trees harvested this October in order to have sufficient ON- and OFF-crop trees with which to conduct the proposed research. During bloom of both years of this research, we will also sample flowers to determine treatment effects on the number of perfect vs. staminate flowers. Our efforts to obtain this data in spring 2012 were not successful, but we learned how to accomplish this. Taken together, these data will help to identify the best PGR treatment and the optimal time to spray the foliage to mitigate AB in olive in the future.

Expected outcomes: We anticipate that the PGR treatments in February (only) following an ON-crop will increase spring bud break and floral intensity of ON-crop trees to a value significantly greater than untreated ON-crop trees but not equal to OFF-crop trees. We anticipate that July 2012 PGR treatments will increase summer vegetative shoot growth during the ON-crop year and when combined with February 2013 PGR treatments will increase bud break, floral intensity and the number of perfect flowers the spring following the ON-crop to a value significantly greater than untreated ON-crop trees and equal to that of OFF-crop trees.

Literature Cited:

Sibbett, S. 2000. Alternate bearing in olive trees. California Olive Oil News. Vol. 3, Issue 12.

BUDGET REQUEST – Lovatt and Fichtner

Budget Year: 1 February 2013 – 31 December 2013

Funding Source:

Salaries and Benefits:

Postdocs/RA's 3,811

Toan Khuong @ $ 3,811/mo. variable time equivalent to 100% x 1 mo.
(Under my supervision, assists in laying out the experiment in the orchards, making maps, treatment applications, flower and fruit counts, shoot growth (node counts) data management, data sheets, fruit, data entry, and statistical analyses of the data.)

SRA's and Lab/Field Assistance

TBA Lab Assistant II @ $ 2,773/mo. variable time equivalent to 100% x 1mo. 2,773
(To assist with laying out the experiments in the orchards, treatment applications, harvest, shoot measurements and flower and fruit counts.)

TBA Lab Assistant I @ $ 2,498/mo. variable time equivalent to 100% x 1 mo. 2,498
(To provide assistance with all shoot measurements, flower and fruit counts, and harvest.)

Subtotal Sub2 9,082

Employee benefits:

TK = $3,811 x 66.5%	2,534
TBA Lab Asst II = $2,773 x 34.5%	957
TBA Lab Asst I = $2,498 x 34.5%	862

Sub6 4,353

TOTAL 13,435

Supplies and Expenses Sub3 3,975

Field supplies, PGRs, buffer, drill, syringes, sample jars and FAA to store flower samples to quantify perfect vs. staminate flowers, microscope slides = $500
Recharge to the Lindcove REC: use of olive grove, water, fertilizer, etc. = $1,619; fruit removal = $480; harvest = $1,376

Equipment Sub4 0

Travel Sub5 12,142

14 roundtrips to Exeter
(520 mi x 14 = 7,280 mi x $0.6014 = $4,378;
UCR vehicle rental 28 days x $47.268/day = $1,324
$115/day per diem x 4 people x 14 trips (1.5 days each) = $6,440

SUBCONTRACT Sub7 9,661

Elizabeth Fichtner, Farm Advisor, Orchard Systems, Cooperative Extension,
4437 S. Laspina St., Tulare, CA 93274

Department account number: AO1082 TOTAL 39,213

Originator's Signature Carol J. Lovatt Date 10/19/2012

COOPERATIVE EXTENSION

County Director: ____________________ Date ____________

Program Director: ____________________ Date ____________

AGRICULTURAL EXPERIMENT STATION
Department Chair: Michael L Roose Date 10/19/2012

UC COC LIAISON OFFICER: ____________________ Date ____________

BUDGET SUBCONTRACT

Budget Year: 1 February 2012 – 31 December 2012

Elizabeth Fichtner
Farm Advisor, Orchard Systems, Cooperative Extension,
4437 S. Laspina St., Tulare, CA 93274

Funding Source:

Salaries and Benefits:

Postdocs/RA's

SRA's and Lab/Field Assistance

		6,408
SRAII @ 60% time for 2 month (includes EB)		
Subtotal	Sub2	0
Employee benefits:		
	Sub6	0
	TOTAL	6,408
Supplies and Expenses	Sub3	500
Field supplies: bags ribbons, cooler box, tree sealant		
Equipment	Sub4	0
Travel	Sub5	1,796
28 round trips to Exeter x 28 mi. x $0.6014/mi.= $472 28 round trips to Exeter x $47.268/day = $1,324		
	SUBTOTAL	8,704
UC ANR Overhead @11% $8,704 x 11% =	Sub6	957
	SUBCONTRACT TOTAL	$9,661

Elizabeth Fichtner, Farm Advisor, Orchard Systems, Cooperative Extension,
4437 S. Laspina St., Tulare, CA 93274

Date ________________

Originator's Signature

COOPERATIVE EXTENSION

County Director: ____________________________________ Date ________________

Program Director: ___________________________________ Date ________________

AGRICULTURAL EXPERIMENT STATION

Department Chair: ___________________________________ Date ________________

UC COC LIAISON OFFICER: ____________________________ Date ________________

COOPERATIVE EXTENSION

County Director: ______________________ Date 10/19/2012

Program Director: Elizabeth ______________________ Date 10/19/2012

AGRICULTURAL EXPERIMENT STATION

Department Chair: ______________________ Date ____________

UC COC LIAISON OFFICER: ______________________ Date ____________

Table 1. **Hypothesis 1: The ON-crop reduces return bloom in olive by inhibiting bud break for summer vegetative shoot extension growth in Year 1 (2011).**

Tree/shoot status (2011)	Fruit per shoot	Net shoot growth and nodes per shoot 15 July – 17 Aug		18 Aug – 4 Oct	
		--mm--	*-- no.--*	*--mm--*	*--no.--*
OFF/-fruit	0.0 b	24.0 a	1.3 a	1.0a	0.1 a
ON/-fruit	0.0 b	9.0 b	0.6 b	1.0 a	0.1 a
ON/+fruit	22.8 a[z]	0.0 c	0.1 c	0.0 a	0.1 a
P-value	< 0.0001	< 0.0001	< 0.0001	0.4004	0.6024

[z] Values in a vertical column followed by different letters are significantly different at the *P*-values specified by Fisher's protected LSD.

Table 2 (Part A). **Hypothesis 2: The ON-crop inhibits summer vegetative shoot growth by causing auxin > cytokinin in buds; injecting an auxin-transport inhibitor an/or cytokinin in summer increased vegetative shoot growth (ON/-fruit) in Year 1.**

Tree/shoot status (2012)	New nodes per shoot (Jun-Sept)	Number of fruit per shoot Aug	Sept
OFF/-fruit	3.4 a[z]	0.0. d	0.0 f
ON/-fruit	0.7 e	0.0 d	0.0 f
TIBA+BA	3.3 ab	0.0 d	0.0 f
*TIBA+PCK	3.8 a	0.0 d	0.0 f
*NAR+BA	3.5 a	0.0 d	0.0 f
NAR+PCK	3.1 abc	0.0 d	0.0 f
*TIBA	3.8 a	0.0 d	0.0 f
*NAR	3.5 a	0.0 d	0.0 f
BA	3.4 ab	0.0 d	0.0 f
PCK	3.2 abc	0.0 d	0.0 f
P-value	< 0.0001	< 0.0001	< 0.0001

[z] Values in a vertical column followed by different letters are significantly different at the *P*- values specified by Fisher's protected LSD.

Table 2 (Part B). **Hypothesis 2: The ON-crop inhibits summer vegetative shoot growth by causing auxin > cytokinin in buds; injecting an auxin-transport inhibitor an/or cytokinin in summer increased vegetative shoot growth (ON/+fruit) (Year 1).**

Tree/shoot status (2012)	New nodes per shoot (Jun-Sept)	Number of fruit per shoot Aug	Sept
OFF/-fruit	3.4 a[z]	0.0. d	0.0 f
ON/-fruit	0.7 e	0.0 d	0.0 f
ON/+fruit	0.6 e	8.6 c	8.4 e
TIBA+BA	3.3 ab	10.9 a	11.1 a
*TIBA+PCK	3.8 a	9.2 bc	9.1 cde
*NAR+BA	3.5 a	10.7 a	10.7 ab
NAR+PCK	3.1 abc	8.8 bc	8.5 de
*TIBA	3.8 a	9.6 abc	9.3 bcde
*NAR	3.5 a	9.9 ab	10.5 abc
BA	3.4 ab	9.6 abc	10.0 abcd
PCK	3.2 abc	9.0 bc	9.0 de
P-value	< 0.0001	< 0.0001	< 0.0001

[z]Values in a vertical column followed by different letters are significantly different at the *P*- values specified by Fisher's protected LSD.

Table 3. **Hypothesis 3: The ON-crop reduces the floral intensity of the return bloom in olive in Year 2 (2012).**

Tree/shoot status (2011)	Inflor. per 5 shoots (2012)	% Bud break of floral buds (spring 2012) Nodes 1-5	Nodes 6-10	Nodes 11-15	New nodes BB-May
	--no.--	*---------- % of Total inflor. ----------*			*--no.--*
OFF/-fruit	**76.8 a[z]**	**142.7 a**	**108.8 a**	**48.6 a**	**8.7 b**
ON/-fruit	**66.6 a**	**129.1 a**	**90.7 a**	**57.3 a**	**16.7 a**
ON/+fruit	**3.8 b**	**14.7 b**	**0.0 b**	**2.0 b**	**16.7 a**
***P*-value**	**0.0018**	**0.0002**	**0.0060**	**0.0275**	**0.0006**

[z]Values in a vertical column followed by different letters are significantly different at the *P*-values specified by Fisher's protected LSD.

Table 4 (Part A). **Hypothesis 4: Bud break, not floral development, is inhibited on shoots without fruit on ON-crop olive trees; PGRs known to increase spring bud break increased inflorescence number in Year 2 (2012).**

Tree/shoot status (2011)	Inflor. per 5 shoots (2012)	% Bud break of floral buds (spring 2012) Nodes 1-5	Nodes 6-10	Nodes 11-15	New nodes BB-May
	--no.--	----------- % of Total inflor. -----------			--no.--
OFF/-fruit	76.8 b^z	142.7 ab	108.8 bcd	48.6 de	8.7 cdefg
ON/-fruit	66.6 bc	129.1 abc	90.7 cd	57.3 cd	16.7 ab
Jan TIBA+BA	52.6 bcd	88.6 cdefg	89.6 cd	45.6 de	9.0 cdef
†Feb TIBA+BA	81.5 ab	121.3 abcd	123.4 abc	81.1 bcd	13.5 abc
†Feb NAR+BA	84.3 ab	112.0 abcedf	127.7 abc	109.1 ab	14.0 abc
†Feb TIBA+PCK	79.0 ab	121.1 abcd	111.5 bcd	76.5 bcd	12.1 bcd
Feb NAR+PCK	43.3 cde	66.0 fgh	73.1 d	45.8 de	15.5 ab
*Feb BA	110.0 a	155.9 a	158.1 a	103.6 ab	9.4 cde
*Feb PCK	111.0 a	138.3 ab	150.3 ab	127.4 a	8.0 defg
†Mar TIBA+BA	76.6 b	102.1 bcdefg	128.5 abc	78.7 bcd	16.0 ab
†Apr TIBA+BA	79.8 ab	116.0 abcde	125.6 abc	93.2 abc	16.0 ab
P-value	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

Table 4 (Part B). **Hypothesis 5: Bud break or floral development may be inhibited on shoots with fruit on ON-crop trees since PGRs did not significantly increase return bloom Year 2 (2012).**

Tree/shoot status (2011)	Inflor. per 5 shoots (2012)	% Bud break of floral buds (spring 2012) Nodes 1-5	Nodes 6-10	Nodes 11-15	New nodes BB-May
	--no.--	----------- % of Total inflor. -----------			--no.--
OFF/-fruit	76.8 b^z	142.7 ab	108.8 bcd	48.6 de	8.7 cdefg
ON/-fruit	66.6 bc	129.1 abc	90.7 cd	57.3 cd	16.7 ab
ON/+fruit	3.8 f	14.7 I	0.0 e	2.0 b	18.3 a
†Jan TIBA+BA	16.3 ef	59.2 ghi	5.8 e	0.0 f	7.1 defgh
Feb TIBA+BA	17.8 ef	62.7 ghi	9.0 e	0.0 f	5.8 efgh
†Feb NAR+BA	19.3 ef	68.6 efgh	9.1 e	0.7 f	7.4 defgh
*Feb TIBA+PCK	24.3 def	77.1 defgh	16.6 e	9.1 ef	5.0 efgh
Feb NAR+PCK	10.3 f	34.5 hi	8.5 e	0.0 f	2.4 h
Feb BA	20.4 ef	66.3 fgh	14.6 e	5.7 f	3.4 gh
*Feb PCK	25.7 def	70.3 efgh	23.2 e	10.4 ef	5.5 efgh
*Mar TIBA+BA	24.2 def	81.0 defgh	12.0 e	3.6 f	5.4 efgh
Apr TIBA+BA	21.0 def	73.3 defgh	17.8 e	0.7 f	3.7 fgh
P-value	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

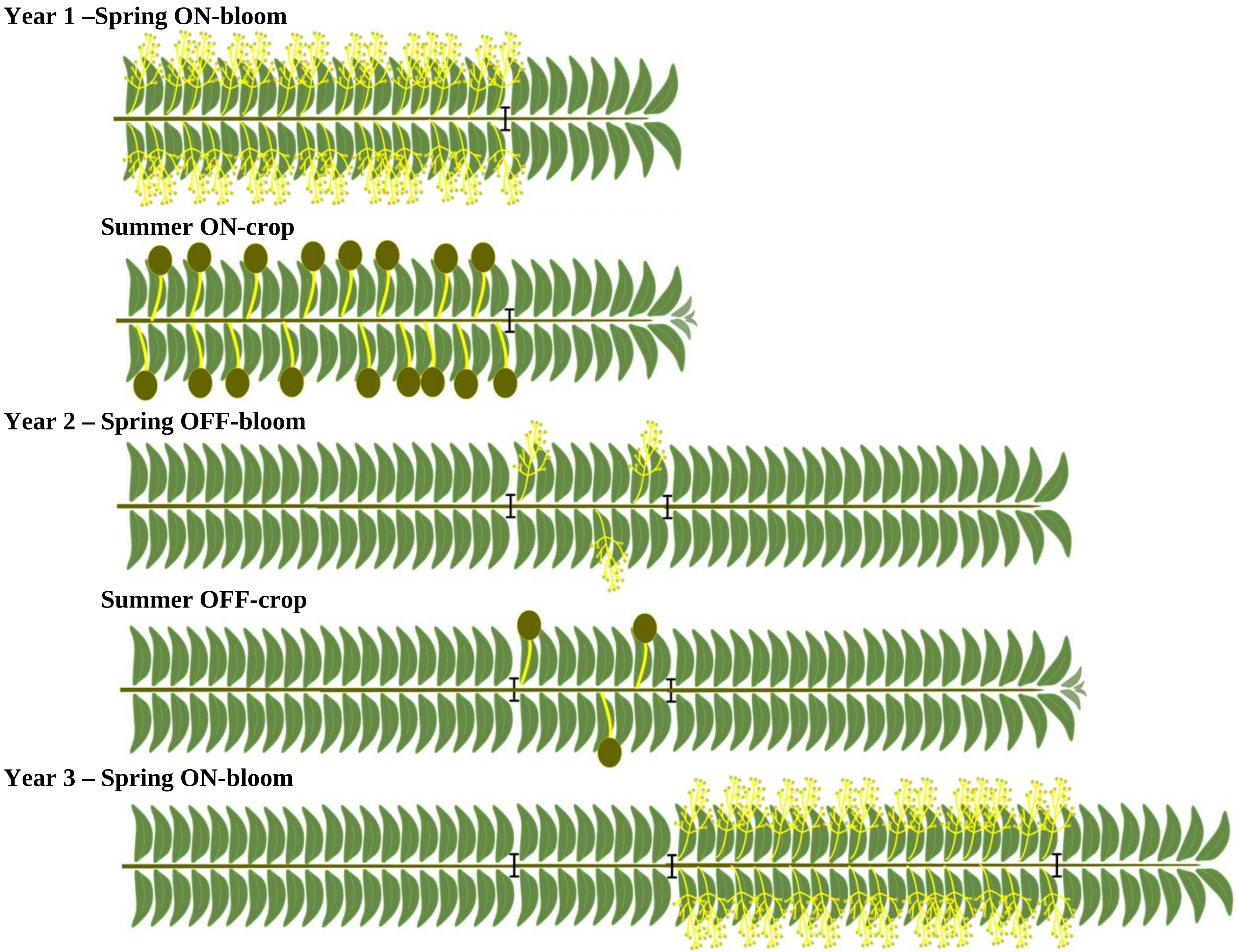

Fig. 1. Alternate bearing in 'Manzanillo' olive. Year 1 ON-crop trees produces little vegetative shoot growth and an OFF-bloom in spring of Year 2 but also produces significant vegetative shoot extension growth in Year 2 that in turn produces an ON-bloom and little vegetative shoot growth in spring of Year 3, which will result in an OFF-bloom in Year 4.

CALIFORNIA OLIVE COMMITTEE

CONCEPT PROJECT PLAN/RESEARCH GRANT PROPOSAL

Workgroup/Department: Olive / Plant Sciences, UC Davis

Project Year 2013 Anticipated Duration of Project: One Year

Project Title: **Improving Mechanical Harvesting Efficiency with Engineering and Pruning**

Project Leaders:

Louise Ferguson, Extension Specialist, Department of Plant Sciences, 2037 Wickson Hall, Mail Stop II, UC Davis, 1 Shields Ave., Davis CA 95616, (530) 752-0507 [Office], (559) 737-3061 [Cell], LFerguson@ucdavis.edu

Dr. John Miles, Professor Emeritus, Department of Biological and Agricultural Engineering, University of California, Davis, JAMiles@ucdavis.edu.Edu

Dr. Sergio Castro-Garcia, Asst. Professor**,** Department of Rural Engineering, University of Cordoba, Cordoba, Spain. Ir1casgs@uco.es

Cooperating Individuals:
Elizabeth Fichtner PhD: Tulare County Farm Advisor: EJFichtner@UCANR.Edu
William Krueger MS: Glenn County Farm Advisor Emeritus: WHkrueger@UCNR.Edu

Cooperating Ranches:
Rocky Hill Ranch; Exeter California: Mark Pascoe; Pascoe32@MSN.com
Nickels Soils Laboratory; Arbuckle: Stan Cutter; CutterFarms@Frontier.net

Commodity: Olive Relevant AES/CE Project No.

Year Initiated: 2013 Current Funding Request**: 91,478.00**

Problems and Significance:
California black ripe table olive production, with its current combination of hand decreased labor availability, skill and cost, and per ton return to the grower, is not sustainable. The only solution is to decrease harvest costs through a combination of improving both the current experimental harvester technologies and tree pruning to increase harvesting efficiency.

<u>Summary of major Results: 2006 – 2012: 2012 Results in Bold</u>

I. Mechanical Harvester Engineering Improvements:

- To remove 'Manzanillo' olives requires a canopy contact harvester head speed of 300 rpm and 5 inches of displacement (2006 - 2008).
- Unacceptable fruit damage comes primarily from the canopy contact harvester rods and was significantly decreased with Shore 60A padding and looser rod padding that decreased impact bruising (2006 - 2008).
- Both trunk shaking and improved canopy contact harvesting technologies deliver mechanically harvested olives that receive total adjusted prices per ton and canning percentages, and sensory and consumer evaluations of the processed fruit, that are statistically equal to those of hand harvested fruit. (2006 – 2012)
- **The drive shaft and bearings were redesigned and strengthened, the boom was shortened and repositioned to improve visibility and the rings of rods were decoupled to move independently. (2012)**
- **The rod attachment to the harvester head needs to be redesigned to avoid breaking the rods on harder wood. (2012)**
- **Initial economic analysis:**
    - **At the current speed harvester speed of 3 min./per tree (202 trees per acre) with a rolling catch frame the harvester would require 5 weeks of 10 hour days to harvest 30 acres if operated as a single unit.**
        - **202 trees/acre X 3 min./tree = 606 min./acre or 10 hrs. /acre**
        - **With a double-sided machine: 5 hrs. /acre.**
        - **30 acres X 5 hrs. /acre = 150 hours or 15 days or 2+ weeks for 30 acres.**
    - **This canopy contact head can be fabricated for approximately 25,000. If mounted on a rented ($3,000.00/month) Bobcat for mobility and a power source and adding an operator totaling 35,000/month, or 75,000 estimated for 2 units for a month.**
    - **The double unit would need to harvest 60 acres; at 3 tons/acre at a cost of $425.00/ton to equal what hand labor would cost to pay for heads, bobcat rentals and operators within the first season.**
    - **With the suggested improvements, a catch frame and experienced operators the harvest time per tree could be reduced by 50%, to 1.5 minutes/tree.**

II. Effects of Mechanical Pruning on Final Harvester Efficiency:

- Mechanically hedging and topping significantly increased canopy contact harvesting efficiency by 7%. (Rocky Hill: 2010)
- Fruit on shoots above 12' and in the row between trees are not harvestable, and sometimes not catchable, by canopy contact harvesters, and should be removed. (2011)
- Branches between 180 and 90* will be damaged by the canopy contact harvesters and should be removed. (2011)
- Damage by the canopy contact harvester is less severe than that by hand harvesters: Rocky Hill: < 0.2%. (2011)

- **<u>Rocky Hill Ranch: 139 trees/acre.</u>**
- **Yield was so low in 2012 due to weather related crop failures that mechanical harvesting was not attempted, as the result would have been invalid.**

- **<u>Nickels Soils Laboratory: 202 trees per acre.</u>**
- **The average final harvest efficiencies of the canopy of the prototype canopy contact harvester were 70% (ranging from 63% to 75%) with hand pruned hedgerow trees and 77% (ranging from 75% to 83% efficiency) with mechanically pruned hedgerow trees. (Nickels Soils Laboratory: 2012)**
- **The average time for a single sided canopy contact harvester to mechanically harvest a mechanically pruned hedgerow tree was approximately 3.00 minutes and 4.78 minutes for a hand pruned hedgerow tree. (Nickels Soils Laboratory: 2012)**
- **The hand pruned hedgerow trees broke the harvester head rods 13 times greater frequency than the mechanically pruned trees. (Nickels Soils Laboratory: 2012)**

<u>III. Effects of Mechanical Pruning on Yield and Quality:</u>

- **<u>Rocky Hill Ranch: 139 trees/acre</u>**
- **Over the 5 years of mechanical pruning the hedged and topped trees yielded 3.1 tons per acre annually versus 3.2 tons per acre for hedged trees and 3.1 per acre for hand pruned controls. Over 5 years mechanical topping and hedging has not significantly decreased annual average yields. (2008 – 2012)**

- **<u>Nickels Soils Laboratory: 202 trees per acre</u>**
- **In the first 2 years of this mechanical pruning trial hand pruned trees have yielded a cumulative total of 5.89 tons per acre for an average annual yield of 2.95 tons versus 7.05 tons/acre and an average annual yield of 3.53 tons per acre for the mechanically pruned trees. The hand pruned control trees had higher percentages of larger and more valuable fruit that ripened earlier. (2011 and 2012)**

- **At both locations the mechanical pruning is demonstrating it can mitigate alternate bearing but will take a total of 8 years total at each location to prove this as a reliable production practice. (2008 – 2012)**

Proposed Objectives for 2012:
Objective I. Improving the Canopy Contact an Harvester Technology

Background:
Trunk Shaking Harvesters:
The 2011 and 2012 results of our Spanish cooperator, Dr. Sergio Castro-Garcia, Department of Rural Engineering at the University of Cordoba in Cordoba, Spain and by independent commercial trials in California in 2012 with ENE Inc. demonstrate we no longer need to work on development or evaluation of trunk shaking harvesters. This development of trunk shaking harvesters for California black ripe processed table olives has now been assumed by the commercial harvester industry.
Canopy Contact Harvesters:
The 2012 field trials demonstrated the harvest head rods break at collar attachment to the head, particularly in the harder wood of older trees. The rod attachment needs to be redesigned.
The 2012 trials also demonstrated developing a catch frame would greatly enhance the ability to get more accurate data.

Hypothesis I:
Incorporating the above engineering changes into the canopy contact harvester will increase the canopy contact harvester efficiency.

Objective IIA and IIB: Improving Canopy Contact Harvester Efficiency with Mechanical Pruning to Shape the Canopy:

Background:
Results from 2006 through 2012 have demonstrated fruit between trees within the row and on the treetops is more difficult to harvest efficiently than olives on the canopy facing the row middle. This suggests trees pruned or trained into hedgerows with the top fruit pruned off should increase final harvester efficiency.

Hypothesis: IIA: (193 tree/acre hedgerow) and IIB: (202 tree/acre hedgerow):
Mechanical topping and one-sided hedging combined with skirting in a two-three year cycle, combined with selective hand removal of: (*reason for removal in italics*)
1. **Fruit bearing branches between trees in the row (*fruit is unharvestable by canopy contact harvester*).**
2. **All branches between 180 and 90* extending into the row middle. (*Branches are damaged by canopy contact harvester*)**

Will increase the canopy contact harvester efficiency, and decrease alternate bearing.

<u>Experimental Procedures:</u>
<u>Objectives 1 and IIA: testing of canopy contact harvester in 139-trees/acre hedgerows.</u>
Mechanical Pruning Trial with Canopy contact Harvester
Rocky Hill Ranch, Exeter, Tulare County: Manager, Mark Pascoe
Block 17 W:
17-year-old 'Manzanillo' orchard with 'Sevillano' pollinators (irregularly placed)
13, 83 tree, rows spaced at 13' X 26' (139 trees per acre)

<u>Pruning Treatments</u>: May- June 2013
Split plot with 6 hand-pruned and 6 mechanically pruned rows (replications)
Treatments: (late May to early June 2013 with Laux Pruning)

I. Mechanically top half of the 6 rows 12' from ground, and hedge all 6 rows on east side 4' from the trunk and skirt 4' from ground.
   a. Remove all large shoots bearing crop between trees will be removed.
   b. Remove all branches between 180 and 90* degrees extending directly into the row will be removed.

II. Hand pruned control; 6 eastern rows. All tree skirted 4' from ground (for harvester catch frame).

III. Crop will be thinned with NAA.

<u>Data Collection</u>: September - October 2013.

1) Fruit removal force and individual fruit weight will be determined on 100 individual fruits/row.
2) Hand harvest 10 trees for hand harvest fruit quality controls from all 12 rows.
3) Mechanically harvest remaining 73 trees in 6 mechanically pruned and 6 hand pruned rows.
4) Fruit removal force and individual fruit weight will be determined on 100 individual fruits per row.
5) Trees will be rated for damage: (and potential olive knot development)
   a) Branches with significant remaining fruit will be mapped, tagged for removal, and pruned out after hand harvest.
   b) Branches with significant damage will be mapped, tagged for removal after hand harvest.
6) Hand-glean past the mechanical harvester in both sets of 6 rows.
7) Bins from hand harvest control, machine harvest and postharvest hand gleaning harvests will be:
   a) Bins delivered reweighed at Musco Exeter receiving station.
   b) Receive a COC grade and adjusted value per ton at Musco receiving station.

<u>Harvester final % efficiency for calculation or both machine and hand pruned treatments:</u>

$$\frac{\textbf{Weight of machine harvested olives}}{\textbf{Weight of machine harvested + hand gleaned olives}}$$

<u>Fruit quality and value of the machine and hand harvested olives will be based on:</u>
Yield per tree/or acre
Adjusted price per ton; based on fruit grading (size and quality)
Total canning percentage

Post processing of harvested samples is no longer necessary as the two years' evaluations of processed fruits (2008/9, 2010/11) have demonstrated mechanical harvesting can produce mechanically harvested processed olives that neither sensory or consumer panels can distinguish from hand harvested olives. Therefore, the receiving station grades can serve as indictors for the processed quality

<u>Experimental Procedures: Objectives I and IIB.</u>
<u>Mechanical Pruning Trial with Canopy Contact Harvester: 202 trees per acre hedgerow.</u>
Nickels soils Laboratory, Arbuckle, Colusa County, California: Stan Cutter, Manager
11 year-old 'Manzanillo' orchard with center Sevillano pollinator row
Olive Hedgerow Block: 13, 31 tree, rows of spaced at 12' X 18' (202 trees per acre)

Split plot with 4, 3 row replications split into 15 tree hand-pruned and mechanically pruned halves.

Treatments: (late May to early June 2013 with ENE Inc.)

I. Mechanical topping 12' from ground, west side hedging 2' from trunk and skirted 4' from ground for mechanically pruned treatment.
   a. All large shoots bearing crop between trees will be removed.
   b. All branches between 180 and 90* degrees extending directly into the row will be removed.

II. Hand pruned control will simulate mechanical pruning but be done by hand.

III. Trees will be thinned with NAA

<u>Data Collection</u>: September - October 2013.

8) Fruit removal force and individual fruit weight will be determined on 100 individual fruits/row within each pruning treatment.
9) Hand harvest 3 trees for hand harvest fruit quality controls from each pruning treatment in all 12 rows.
10) Mechanically harvest remaining 12 rows, keeping weights from 12 mechanically and 12 hand pruned tree treatments separate.
11) Fruit removal force and individual fruit weight will be determined after mechanical harvesting on 100 individual fruits within each pruning treatment within each row.
12) Trees will be rated for damage:
    a) Branches will significant remaining fruit will be mapped, tagged for removal, and pruned out after hand harvest.
    b) Branches with significant damage will be mapped, tagged for removal after hand harvest.
13) Hand-glean past the mechanical harvester within both pruning treatments on all 12 rows.

14) For each pruning treatment bins from hand harvest control, machine harvest and postharvest hand gleaning harvests will be:
    a) Bins delivered reweighed at Musco Orland receiving station.
    b) Receive a COC grade and adjusted value per ton at Musco receiving station.

Harvester % efficiency for both machine and hand pruned treatments will be calculated as follows:

$$\frac{\textbf{Weight of machine harvested olives}}{\textbf{Weight of machine harvested + hand gleaned olives}}$$

Fruit quality and value of the machine and hand harvested olives will be based on:
Yield per tree/or acre
Adjusted price per ton; based on fruit grading (size and quality)
Total canning percentage

Post processing of harvested samples is no longer necessary as the two years' evaluations of processed fruits (2008/9, 2010/11) have demonstrated mechanical harvesting can produce mechanically harvested processed olives that neither sensory or consumer panels can distinguish from hand harvested olives. Therefore, the receiving station grades can serve as indictors for the processed quality

Desired Results:
Objective I: Mechanical harvester improvements will increase average final harvester efficiency to 80% or more.

Objective IIA and IIB: Demonstrate mechanical pruning and hedgerow training will increase canopy contact mechanical harvesting efficiency versus hand pruned trees.

BUDGET REQUEST: 2012

BUDGET REQUEST – Part I

Budget Year: 2013-2014 Funding Source: COC

Salaries & Benefits:		
Dr. John Miles: Professor Emeritus (Agricultural Engineer)		
9,800.50/month + 2.8% @ 20%		24,180.00
Farnam Vannucci: Mechanician		6,172.00
$4170.00 /month + 48% @ 1 month		
William H. Krueger: Glenn County Farm Advisor Emeritus		3,000.00
Elizabeth J. Fichtner: Tulare County Farm Advisor		2,000.00
	Sub 1	**35,352.00**
Equipment Supplies & Expenses:		
Harvester Development and Transport Costs:		
Biological and Agricultural Engineering Shop Fees		
40 hrs. @ 59/hr.		2,360.00
Investigate and fabricate better rod attachment to harvester head rings		
Materials:		
Hardware for rod design evaluations and repairs.		5,000.00
Harvester Transportation: two plots (Dr. Miles will drive tractor trailer)		3,500.00
Harvester Development Costs		**10,860.00**
Sub 2		**46,212.00**
Pruning and Harvesting Costs: (based on previous year's cost)		
Mechanical pruning and brush shredding at Rocky Hill (Laux Pruning)		2,500.00
Mechanical (ENE Inc.), and hand pruning, brush shredding: Nickels Estate		2,000.00
Hand harvesting costs at Rocky Hill Orchards: Villapando AGI		15,000.00
Hand harvest and hauling at Nickels Estate: Contracted through Nickels		5,000.00
Miscellaneous harvest supplies: water, gloves, tarps, buckets		1,000.00
Total pruning and harvesting costs:		**25,500.00**
Sub 3		**71,712.00**
Experimental Travel Costs:		
Truck lease and gas: 50% split with pistachio projects:		**8,000.00**
Travel costs during Rocky Hill Harvests: 3 people @ 150/day and 6 days		**2,700.00**
Sub 4		**10,700.00**
	Sub	**82,412.00**
UC Overhead @ 11%	**Sub 5**	**9,066.00**
TOTAL BUDGET		**91,478.00**

UNIVERSITY OF CALIFORNIA

	Originator's Signature	11/06/2011 Date
Agricultural Experiment Station	Department Chair	Date
	Liaison Officer	Date

Scope of Work

Dr. Louise Ferguson:
Responsible for overall coordination of the project, applying pruning treatments, executing harvest trials, data collection and analysis and writing final report.

Dr. John Miles:
Responsible for engineering design and improvement of harvester, and writing final engineering report. Responsible for supervising Farnam Vannucci within Biological and Agricultural Engineering shop and in field experiments.

Dr. Sergio Castro-Garcia:
Responsible for consulting on design and engineering improvements of harvester, supplying supporting information from parallel trials conducted in Spain.

Farnam Vannucci: Responsible for executing engineering improvements under supervision of Dr. Miles and for assisting in field trials

Dr. Elizabeth Ficthner: Responsible for mapping damaged branches and assessing potential for olive knot disease development at Rocky Hill Ranch in Tulare County.

William Krueger: Responsible for hand pruning treatment in Nickels trial and co-coordinator of harvesting trial in Colusa County.

External Contractors: contracts to be secured after funding.

Pruning Contract at Rocky Hill Ranch: Exeter, California
Gary Laux
Laux Management
1359 W Teapot Dome Avenue
Porterville, CA 93257-9378
Office: 559-781-0500 or 781-3116
Cell: 559-783-3212

Pruning Contract at Nickels Soils Laboratory: Colusa, California
Gavin Nielsen or Hillary Nielsen Porter
ENE Inc.
4453 County Road O
Orland CA 95963
ENE@EneInc.com
Office: 800-844-9409
FAX: 530-865-4845

Harvest Contractor at Rocky Hill Ranch: Tulare County

Antonio Villapando
Villapando AGI
Box 388
Woodlake, CA 93286
AVFarmLabor@yahoo.com
Office: 559-564-8071
FAX: 559-564-8050
Mobile: 559-805-3224

CALIFORNIA OLIVE COMMITTEE

CONCEPT PROJECT PLAN/RESEARCH GRANT PROPOSAL

Workgroup/Department: Olive / Plant Sciences, UC Davis

Project Year 2013 Anticipated Duration of Project: One Year

Project Title:
Propagating Dwarfing Olive Rootstocks and Establishing a Long Term Orchard

Project Leaders:

Louise Ferguson, Extension Specialist, Department of Plant Sciences, 2037 Wickson Hall, Mail Stop II, UC Davis, 1 Shields Ave., Davis CA 95616, (530) 752-0507 [Office], (559) 737-3061 [Cell], LFerguson@ucdavis.edu

Dr. John Preece, Curator, USDA National Clonal Germplasm Repository, Davis CA. JAMiles@ucdavis.edu.Edu
Dr. Tziano Caruso, University of Palermo, Palermo, Italy: Tziano.Caruso@unipa.it
Dr. Guilana Marino, University of Palermo, Palermo, Italy: giulia.marino@unipa.it
Dr. Kate Scow, Director, Russell Ranch Agriculture Sustainability Institute: KMScow@ucdavis.edu

Commodity: Olive Relevant AES/CE Project No.

Year Initiated: 2013 Current Funding Request**:**

Problems and Significance:
To facilitate mechanical harvesting the newest table olive orchards are planted in hedgerows and require regular mechanical pruning to keep the trees small.

Such plantings and mechanical harvesting could be facilitated if, rather than cultivars propagated by cuttings and grown on their own roots, they could be grafted on dwarfing rootstocks. This could have favorable impacts on productivity in a manner similar to apples grafted onto dwarfing rootstocks.

The National Clonal Germplasm Repository for Tree Fruits, Nut Crops, and Grapes is a USDA-ARS facility that operates in collaboration with UC Davis and maintains the national collection of olives. The collection consists of more than 200 genetically different olives, some with slow growth and potential as dwarfing rootstocks.

Among those olives with promise for use aa dwarfing rootstocks are: Nikitskaya (there are 60 rooted cuttings), *Olea cuspidate* (65 rooted cuttings), Verticillium Resistant Oblonga Seedling

(68 rooted cuttings) and Dwarf D (20 rooted cuttings, more rooting is necessary). Additionally, our cooperators at University of Palermo and in University of Cordoba in Spain are willing to contribute promising cultivars.

We propose to propagate these rootstocks and test them for their dwarfing potential with 'Manzanillo' to produce a tree that is more amenable to mechanical harvesting.

Simultaneously, we are negotiating with Dr. Kate Scow, Director of the Long Term Research for Agricultural Sustainability project maintained at the Russell Ranch, http://ltras.ucdavis.edu to establish an orchard that will contain these grafted rootstocks and the next generation of hedgerow orchards for mechanical pruning.

This application for initial funding is for two purposes:

I. Propagation and grafting of the rootstocks with ‘Manzanillo’ scions.
II. Establishing the next generation olive hedgerow orchard at the LTRAS project for evaluation of mechanical harvesters.

Objectives: Experimental Procedures:

Objective I: Develop the procedures for propagating the dwarfing rootstocks

Experimental Procedures:
The following cultivars will be propagated for use as rootstocks: (progress thus far)
Nikitskaya (there are 60 rooted cuttings)
Olea cuspidate (65 rooted cuttings)
Verticillium Resistant Oblonga Seedling (68 rooted cuttings)
Dwarf D (20 rooted cuttings, more rooting is necessary).
Tosca: to be supplied by Dr. Caruso
Leccino Dwarf: to be supplied by Dr. Caruson

Objective II: Establish a 4 acre 10 x 16 hedge row ‘Manzanillo’ table olive orchard at Russell Ranch LTRAS Facility at UC Davis for future mechanical harvesting and other research including evaluation of the rootstock cultivar combinations developed above and future cultivars developed in the international cooperative breeding program we hope to cooperate in with Spain, Italy and other olive producing countries of the world.

Experimental Procedures:
An orchard will be established in Spring 2013 at the Russell Ranch Long Term Research Facility, http://ltras.ucdavis.edu, following the planting procedures outline in the UC Cost Studies: http://coststudies.ucdavis.edu/files/OliveTableSV2011.pdf

BUDGET REQUEST: 2012

BUDGET REQUEST – Part I

Budget Year: 2013-2014 Funding Source: COC

Equipment Supplies & Expenses:
Laboratory materials for Propagation:

Chemicals 1.500.00

Sub 1 1,500.00

Orchard Development Costs:

Orchard Development at Russell Ranch: 14,000.00
4 acres @ 3500.00/acre from UC Cost Study adjusted 272 trees per acre and including stakes and trellis: http://coststudies.ucdavis.edu/files/OliveTableSV2011.pdf

Sub 2 15,500.00

UC Overhead @ 11%: 1,705.00
Sub 5 17,205.00

TOTAL BUDGET 17,205.00

UNIVERSITY OF CALIFORNIA

	Originator's Signature	12/15/2011 Date
Agricultural Experiment Station	Department Chair	Date
	Liaison Officer	Date

Scope of Work

Dr. Louise Ferguson:
Responsible for overall coordination of the project.

Dr. John Preece:
Responsible for directing propagation research.

AES/CE MAR 84

Workgroup: Olive
Department: Plant Pathology/ UCR

University of California
Division of Agricultural Sciences
PROJECT PLAN/RESEARCH GRANT PROPOSAL

Project Year: 2013 Anticipated Duration of Project: 3rd year of 3 years

Principal Investigators: J. E. Adaskaveg

Cooperating: D. Thompson, H. Förster, K. Nguyen, J. Connell (UCCE - Butte Co.), and E. Fichtner (UCCE-Tulare Co.)

Project Title: Epidemiology and management of olive knot caused by *Pseudomonas syringae* pv. *savastanoi*

Keywords: Bactericides, Biological controls, and Systemic Acquired Resistance (SAR) compounds

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JUSTIFICATION/ BACKGROUND

Olive knot caused by the bacterial pathogen *Pseudomonas syringae* pv. *savastanoi* (syn. *P. savastanoi*) is a disease that has been disseminated worldwide with its olive host and occurs in all known olive production regions including California. The pathogen is not seed borne but is spread on wounded vegetative tissue. Disease symptoms include tumors, galls, or knots that may lead to tree defoliation and branch diebacks with subsequent reductions in yield, fruit size, and oil quality. Fruit from diseased trees often have off-flavors. Branch infections that occur in late winter result in water-soaked cavities that contain masses of the bacterial pathogen. As the host begins seasonal growth, a gall develops around the cavity where hyperplasia and hypertrophy of cells occur due to secretion of indole acetic acid (IAA) by the pathogen. Occasionally, secondary knots will form from the extension of lysigenous cavities from the original infection court. Due to some host specificity, pathovars have been proposed for the pathogen occurring on olive, oleander, and ash. Historically, the most susceptible olive cultivars are: Manzanilla, Sevillano, Ascolano, and Mission but many of the newer varieties are also susceptible.

The pathogen is a gram-negative, motile, rod-shaped bacterium with one to four polar flagella. Colonies are whitish to cream-colored and smooth. The optimum temperature for growth is 23 to 24 C. The organism produces a fluorescent pigment on certain media. Acid production occurs on growth media containing glucose, galactose, and other carbon sources. Starch is also utilized as a carbon source.

The pathogen survives in the knots where it produces large numbers of cells throughout the year. Bacterial cells exude to the gall surface during periods of wetness and are readily water splash-dispersed or may be disseminated by insects or birds. The organism can also survive on leaves where it can be found at high populations in the spring. Leaf scars are considered the most common entry points for infection. Leaf and blossom scars caused by any biological (e.g., other diseases), environmental (e.g., freeze cracks), or physical (e.g., mechanical harvesting, pruning) means may serve as sites of infection. The period of susceptibility of injuries is not known and needs to be evaluated. In California, infection occurs mostly during the rainy season (late fall, winter and spring) but the knots do not develop until new growth starts in the spring. Infections can occur at fairly low temperatures (5-10 C) and thus, wetness is the main limiting factor for the disease.

Management of olive knot is difficult. Sanitation and prevention are the most successful strategies. Pruning and removal of the knots should be done during dry periods (i.e., summer and early fall). This will reduce inoculum and will avoid re-infection at pruning sites. Because the bacteria may be carried on pruning shears, frequent disinfection of equipment is necessary. Any horticultural practice such as proper irrigation and fertilization programs that promotes growth and minimizes tree stress and results in less leaf drop will reduce infections. Painting galls with Gallex is an effective therapeutic treatment but is very labor intensive. Spray applications of copper-containing bactericides to protect leaf scars and other injuries have been very effective in minimizing the disease, but they often may need to be repeated to protect new wounds as they appear. A minimum of two applications is usually necessary: one in the fall before the rainy season starts and one in the spring when most leaves have been shed. Recently, new copper formulations have been developed to reduce the metallic copper equivalent while maintaining the efficacy of the treatment. We have been the primary investigators of this research on stone fruit, almonds, walnuts, and citrus in California in cooperation with the major copper registrants. Our evaluations of copper sensitivity in populations of the olive knot pathogen indicated a reduced sensitivity in all isolates, but higher rates of copper were still effective in preventing bacterial growth. Because olive knot infections occur mostly during the rainy period, knowledge on the persistence of treatments is critical. Thus, we will determine the efficacy of copper alone and in mixtures with materials to increase its persistence by inoculating treated twig wounds selected times after application. Rainfall will be simulated using overhead sprinklers in recently established orchards at UC Davis.

Based on efforts of our laboratory, recent advances have been made in bacterial disease control with the identification and development of the antibiotic kasugamycin (commercial name Kasumin) for fire blight management on pome fruit and other bacterial diseases of agronomic crops in the United States and elsewhere. The US-EPA registration of Kasumin is pending in December 2012. This antibiotic has high activity against *Erwinia* and *Pseudomonas* species and moderate activity against *Xanthomonas* species and other plant pathogenic bacteria. Our research continues on fire blight and walnut blight and we have been evaluating the antibiotic against bacterial canker and blast of sweet cherry caused by *Pseudomonas syringae* pv. *syringae* with promising results. Our initial greenhouse and field studies on olive knot where Kasumin-treated twig injuries were inoculated were also very promising. These studies will be continued.

Additionally, we have also been working on sanitation treatments and on biological controls for management of bacterial diseases of tree crops. We demonstrated that quaternary ammonia compounds, guanidine, and chlorhexidine were highly toxic against the olive knot pathogen in in vitro studies. Citrox, a natural product derived from citrus extracts, and the quaternary ammonia sanitizers were also highly effective in disinfecting hard surfaces that were contaminated with *P. s.* pv. *savastanoi*. The quaternary ammonia sanitizers are volatile compounds that do not leave residues, they are not corrosive to equipment, and they are currently being used in olive mills to clean oil extracting equipment. We will continue to work with Decco North America, the registrant of Deccosan 321, to obtain a Section 24C registration for use on harvesting equipment in the orchard. We will also test additional parameters that may affect the efficacy of the sanitizers such as inoculum concentration and post-inoculation treatment time. Although AgriTitan was not effective in our previous field studies, this material will be tested again at higher rates.

Biocontrol controls have several different mechanisms to prevent disease including site exclusion by prolific growth and possibly production of secondary metabolites that function in antibiosis and thus, exclude competitors. Additionally, their persistence may provide a continuous level of protection for extended periods. We have identified two promising materials (i.e., Blossom Protect, Actinovate) that show moderate to high efficacy on fire blight and walnut blight, depending on disease pressure. These and additional biological treatments that have recently become available will be evaluated for control of olive knot. These treatments will be compared to Regalia (an extract of the plant *Reynoutria sachalinensis*) that is currently registered for field use on olive.

There has been a recent increased interest in the use of systemic acquired resistance (SAR) compounds for the management of bacterial diseases. These compounds include acibenzolar-S-methyl (Actigard), ProAlexin, the fungicide quinoxyfen, and an experimental compound from a major chemical company (PM-1). Actigard and quinoxyfen also showed promising results in our studies on fire blight, walnut blight, as well as bacterial spot of tomato. Because these SAR compounds have a longer lasting effect on plant health, they may provide sustainable treatments that could be developed for an integrated approach with other treatments and strategies towards managing olive knot in a highly effective program.

RESEACH OBJECTIVES

1) Collection and characterization of strains of *P. syringae* pv. *savastanoi* -
    a. Survey and collection of strains from major olive producing counties.
    b. Determine genetic variability of populations using molecular approaches.
2) Epidemiology – occurrence of inoculum availability, and period of susceptibility of selected injuries (leaf scars, pruning injuries, etc.) to infection
    a. Monitor galls for production of inoculum over time in relation to favovable environments (e.g., rainfall).

   b. Duration of susceptibility of injuries under different environmental conditions (multiple year studies at different locations and at different times of the year).
3) Evaluate populations of the pathogen for laboratory sensitivity to chemicals and biological agents:
   a. Copper compounds - fixed and non-fixed formulations
   b. Develop baseline sensitivities of the pathogen to appropriate selected agricultural chemicals and antibiotics such as kasugamycin (Kasumin).
   c. Sanitizing agents – quaternary ammonium (Deccosan), titanium dioxide (AgriTitan), Citrox – toxicity in direct exposure studies and efficacy in disinfecting contaminated hard surfaces.
   d. Biologicals - Blossom Protect (*Aureobasidium pullulans),* Actinovate (fermentation product of *Streptomyces lydicus*), Double Nickel 55 (*Bacillus amyloliquifaciens*), and potentially others.
4) Evaluation of the efficacy of protective treatments such as new copper formulations, antibiotics such as Kasumin and Mycoshield, biologicals (biocontrols as indicated above; natural products – Regalia), SAR compounds (acibenzolar-S-methyl - Actigard), ProAlexin, PM-1, quinoxyfen), and combination treatments to determine optimal usage strategies for obtaining high efficacy.
   a. Field trials with and without adjuvants to determine optimal performance (i.e., rates)
   b. Protective (pre-infection) vs. post-infection activity of treatments
   c. Timing studies: Treatment at spring leaf drop or after harvest.
   d. Persistence of different copper treatments with and without the addition of lime or other additives under simulated rain conditions.

PLANS AND PROCEDURES

Survey of strains of* Ps. *pv.* savastanoi *collected from olive groves in different counties in California. Infected olive tissues will be collected in collaboration with farm advisors and PCAs to collect strains of *P.s.* pv. *savastanoi* to determine the genetic diversity using rep PCR with ERIC and BOX primers and sensitivity to selected toxicants.

Evaluation of inoculum production and injury susceptibility. Olive knots will be sampled before and after rainfall events (0 h, 12 h, 24 h, 48 h, 96 h after rainfall) at selected times of the year (e.g., winter, spring, summer) to determine pathogen population levels on the surface of the knots as affected by rain, temperature, and host physiology. The knots will be washed, the wash solutions will be plated out, and bacteria will be enumerated. Additionally, leaf scars or mechanical injuries will be inoculated at different intervals to determine the duration of susceptibility after wound healing occurs. Injuries will be made and inoculated at selected time intervals (e.g., 1, 2, 3, 4 weeks after wounding) in late spring when rain events are unlikely. For these studies, one or two cultivars will be used.

Evaluate populations of the pathogen for laboratory sensitivity to copper, antibiotics, and biologicals. For determination of the in vitro sensitivity, we will use the spiral gradient dilution (SGD) and direct plating on amended agar media. In the SGD assay, suspensions of *P.s.* pv. *savastanoi* will be plated onto selected media in radial streaks across the concentration gradient. Inhibitory concentrations will be determined using a computer program after two days of incubation. This assay will also be used to determine direct interactions between biological control and the olive knot pathogen. Direct plating assays will be used for determining copper sensitivity. Bactericide-amended treatments will be compared to the non-amended control.

In direct contact assays, bacterial suspensions will be incubated with selected concentrations of the test materials. After selected times, the bacterial-test substance mixture will be diluted 1:1000 with sterile water and the resulting suspension will be plated out onto nutrient agar using a spiral plater to establish a gradient of bacterial colonies that can then be enumerated after 2-3 days of incubation. Colony numbers after chemical or biological (competition assays) treatments will be compared to those of the water control. Treatments will be replicated and the experiments repeated. Data for chemical toxicity will be analyzed using analysis of variance and LSD mean separation procedures of SAS 9.1.

***Evaluate the efficacy of sanitizing compounds against* P.s. *pv.* savastanoi**. The toxicity of sanitizing treatments (quaternary ammonia compounds, Citrox) will be determined in direct contact assays as described above and in disinfection studies using hard surfaces. For the latter studies, PVC pipe sections contaminated by dipping in suspensions of *P.s.* pv. *savastanoi* and air-dried will be sprayed with 100 ppm chlorine or 2000 ppm of the other sanitizers, rinsed with sterile water after 90-120 sec, and then vortexed in a centrifuge tube with distilled water. The supernatant will be plated out on KMB agar. The viability of the pathogen by the treatments in comparison to the water control will be determined based on the number of bacterial colonies developing on the plates.

Greenhouse and field studies using protective treatments during the growing season. In greenhouse and field studies (commercial and experimental orchards), leaf scar or lateral twig wounds will be treated by hand-spraying selected times before or after inoculation with *P.s.* pv. *savastanoi* (10^6 to 10^8 cfu/ml). Inoculations sites will be wrapped with Parafilm or twigs will be bagged, or will be left non-wrapped and non-bagged. Treatments in applications at 100 gal/A will include several copper formulations (Kocide 3000, Badge XT, Cueva), Kasumin, streptomycin, oxytetracycline, AgriTitan, and biologicals (Blossom Protect, Actinovate, Double Nickel55) as well as the SAR compounds acibenzolar-S-methyl - Actigard), ProAlexin, PM-1, quinoxyfen. Combination treatments will also be done to develop integrated programs for resistance management. Actigard will also be evaluated as a soil treatment in greenhouse studies. Incidence of new knots on olive branches in addition to potential phytotoxic effects of the treatments will be evaluated. Application timings of these treatments will be determined based on leaf-drop in the spring (host stage) and rainfall events (or after harvest treatments). Each treatment will have six to eight replications with one branch on each tree. Data will be analyzed using analysis of variance and LSD mean separation procedures of SAS 9.1.

The persistence of copper treatments with or without the addition of lime or other materials under simulated rainfall will be evaluated in the experimental orchard at UC Davis. For this, twig wounds will be treated and irrigated weekly by overhead sprinklers and then inoculated. Evaluation of treatments will be done as described above.

Benefits to the industry

For management of olive knot, only copper materials and the natural product Regalia are currently available in addition to cultural and sanitation practices. Recently growers have noticed decreased performance of copper treatments. This may be attributed to reduced sensitivity to copper and possibly to reduced persistence with newer copper formulations. To address this issue the industry wants to use higher rates but this may result in phytotoxicity to trees and in the selection of strains of the pathogen that are less sensitive to copper (eventually completely copper-resistant) if used exclusively. Alternatives are needed for a sustainable and effective management program. For the management of other bacterial diseases of tree fruit crops we have been very successful by using the new agricultural antibiotic kasugamycin that is scheduled for registration in late 2012. Antibiotic treatments registered on other tree fruit crops in California, such as streptomycin and oxytetracycline, also need to be evaluated against olive knot. Additionally, several biologicals (Regalia, Actinovate, etc.) and systemic acquired resistance compounds (e.g., Actigard, quinoxyfen, etc.) are available that have potential for commercial use. Thus, effective alternatives need to be characterized for management of olive knot. The registration of several materials will allow the implementation of anti-resistance strategies and will prevent over-use of any single mode of action bactericide. Still, integrated practices will be critical for the successful management of the disease. Any bactericide or biological treatment will be most effective when pathogen population levels are at a minimum and the host is less susceptible. Thus, removing knots in the summer before mechanical hedging and avoiding mechanical harvest during rainy periods are among practices that should be followed. Surveys on pathogen populations will allow us to determine the natural variability within the pathogen and establish sensitivity ranges for compounds to be tested in the field, whereas sampling of knots and inoculation of injuries over time will indicate appropriate timing and persistence needed of protective treatments.

References

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4. Ogawa, J. M., and English, E. 1991. Diseases of Temperate Zone Tree Fruit and Nut Crops. University of California, DANR, Oakland, CA. Publication 3345. 461 pp.
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Budget Request:

Budget Year: 2013

Funding Source: Olive Board of California

Salaries and Benefits:	Post-Docs/RAs		30,000
	Lab/Field Ass't		8,000
	Subtotal		38,000
	Employee's Benefits*		20,000
		Subtotal	58,000
Supplies and Expenses			0
Equipment and University Land and Orchard charges			3,000
Operating Expenses/Equipment Travel (Davis Campus only)			0
Travel			3,000
Department Account No. ___________		**Total**	**$64,000**

*-Note: Benefits for UC employees have increased dramatically up 27% in the last three years.

James E. Adaskaveg

_______________ Date: Nov. 12, 2012

Originator's Signature (PI)

Dept. Chair Katherine Borkovich _______________ Date: Nov. 12, 2012

(Riverside Campus)

Liaison Officer _______________ Date:_________