CALIFORNIA RIPE OLIVES
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AGENDA

California Ripe Olive
Research Subcommittee Meeting
ZOOM/Conference Call
January 22, 2021
9:00 AM

Join Zoom Meeting
https://us02web.zoom.us/j/87293588498
Meeting ID: 872 9358 8498

Dial-In
1-669-900-6833
Meeting ID: 872 9358 8498#

I Call to Order
- a. Roll Call p.2
- b. Research Subcommittee Chairman's comments
- c. Approval of 11-5-20 Research Subcommittee Minutes (action item) p.3

II. Review of approved 2021 Research Projects p.8

III. Presentation of 2021 Research Proposals p.9
- a. Dr. Ehsani to present second 2021 Proposal

IV. Approval of 2021 Research Project (action item) p.28
- a. Closed Session

V. Other Business

VI. Adjournment

2020 Research Subcommittee

Producer Members:

Carolina Burreson
Michael Silveira
Chris Henderson
Pablo Nerey
Ed Curiel
Vito DeLeonardis
Giulio Zavolta
Pat Ricchiuti
Galen Pfeiffer
Mark Heuer

Handler Members:

Dennis Burreson-Chairman
Matt Miller
John Pieretti
Janet Edwards
Julia Tinsley
Jacob Peters
Sergio Mendez

California Olive Committee
Research Subcommittee Meeting Minutes
ZOOM/Conference Call
November 5th, 2020
10:30 AM

I. CALL TO ORDER

A meeting of the Research Subcommittee was called to order by Chairman Dennis Burreson at 10:34 A.M., and the following members were present:

Members	**Affiliation:**
Carolina Burreson	PRODUCER
Michael Silveira	PRODUCER
Chris Henderson	PRODUCER
Vito DeLeonardis	PRODUCER
Giulio Zavolta	PRODUCER
Pat Ricchiuti	PRODUCER
Galen Pfeiffer	PRODUCER
Dennis Burreson-Chairman	HANDLER
Matt Miller	HANDLER
John Pieretti	HANDLER
Janet Edwards	HANDLER
Julia Tinsley	HANDLER
Jacob Peters	HANDLER
Others Present:	
Todd Sanders	COC
Elizabeth Carranza	COC
Elise Oliver	COC
Kathie Notoro	USDA

With the appropriate number of members from producers and handlers in, a quorum was established.

MOVED by Pat Ricchiuti, duly seconded by Vito DeLeonardis, and unanimously carried THAT the minutes of the 7.21.20 Research Subcommittee meeting be approved. (Motion 11.5.20 #1)

II. Discussion and Review of 2020 Projects

Each year, the Subcommittee funds research projects and request progress reports from researchers. The current research progress reports were provided in the meeting packet. Final reports are due to the COC by December 31, 2020.

III. Presentation of 2021 Proposals

The Subcommittee was provided with all 2021 proposals from each researchers. Each researcher gave a 10-minute presentation to the subcommittee summarizing their full proposal which was included in the packet.

2021 RESEARCH PROPOSALS FOR THE CALIFORNIA OLIVE COMMITTEE

TOPIC	LEADERS	AMOUNT
Timing Ethylene Applications as a Function of Heat Unit Accumulation	Louise Ferguson Giulia Marino	$24,470
Managing Alternate Bearing in Olive with PGRs and Pruning	Carol Lovatt Elizabeth Fichtner	$27,230
Combining Trunk Shaking and Canopy Shaking for a Highly Efficient, Low-Cost Olive Harvester-Part 2	Reza Ehsani Louise Ferguson	$69,997
Precise Water Management Strategies for Table Olive Orchards in California	Giulia Marino Louise Ferguson	$54,303.42
Epidemiology and Management of Olive Knot Caused by Pseudomonas Savastanoi pv. Savastanoi	J.E. Adaskaveg	$31,650
Management of Foliar Diseases of Olive- A. Olive Knot and B. Evaluation of new fungicides for control of olive leaf spot	J.E. Adaskaveg	$10,000
Characterization of Olive Fruit Abscission Zone in Response to Ethylene Applications and as a Function of Developmental Stage	Georgia Drakakaki	$64,260
Southern San Joaquin Valley Olive Fruit Fly Monitoring Project	Jim Stewart	$9,950
Sacramento Valley Olive Fruit Monitoring Project	Ernie Simpson	$6,500
Total * budget estimate; actual budget pending on results		$298,360.42

IV. Approval of 2021 Budget

TOPIC	LEADERS	AMOUNT
Timing Ethylene Applications as a Function of Heat Unit Accumulation	Louise Ferguson Giulia Marino	$24,470
Managing Alternate Bearing in Olive with PGRs and Pruning	Carol Lovatt Elizabeth Fichtner	$27,230
Combining Trunk Shaking and Canopy Shaking for a Highly Efficient, Low-Cost Olive Harvester-Part 2	Reza Ehsani Louise Ferguson	$69,997
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Southern San Joaquin Valley Olive Fruit Fly Monitoring Project	Jim Stewart	$9,950
Sacramento Valley Olive Fruit Monitoring Project	Ernie Simpson	$6,500
2020 NCE Managing Alternate Bearing in Olives with PGRs and Pruning	Carol Lovatt Elizabeth Fichtner	$9,292.80
2020 NCE Control of Overwintering Olive Fruit Fly Using Insect Pathogenic Fungi	Frank Zalom Joanna Fisher	$6,878.4
2021 Contingency Fund		$20,000
Total * budget estimate; actual budget pending on results		$318,360.42- Without NCEs $334,531.62- With NCEs

MOVED by Mike Silveira, duly seconded by Giulio Zavolta, and unanimously carried THAT the Committee fund all above indicated projects for a total of $298,360.42 along with both NCE requests for 2020 projects and a contingency fund of $20,000 bringing the total 2021 FY Research Budget to $334,531.62. (Motion 11.5.20 #2)

V. Approval of Authority to the Executive Director and Chairman to approve No-Cost Extensions

Approval of NCEs was unanimously carried and made in conjunction with approval of 2021 projects in the motion above.

VI. Approval of Authority to the Executive Director and Chairman for Inter-Item Transfers of the Research Subcommittee Budget

MOVED BY Galen Pfeiffer, duly seconded by Giulio Zavolta, and unanimously carried THAT the Committee grant authority to the Executive Director and Chairman for inter-item transfers of the Research Budget. (Motion 11.5.20 #3)

VII. Other Business

Nothing was discussed.

VIII. Adjournment

Research Subcommittee Chairman Dennis Burreson adjourned the Research Subcommittee meeting at 12:55 p.m.

I hereby certify that the above is a full, true and correct copy of the minutes of the meeting held on November 5, 2020 virtually via ZOOM/Conference Call, by the Research Subcommittee.

Elise Oliver

Date: November 5, 2020 Elise Oliver, California Olive Committee

Summary of Motions for November 5, 2020

<u>Motion 11.5.20 #1</u> **APPROVED**

MOVED by Pat Ricchiuti, duly seconded by Vito DeLeonardis, and unanimously carried THAT the minutes of the 7.21.20 Research Subcommittee meeting be approved.

<u>Motion 11.5.20 #2</u> **APPROVED**

MOVED by Mike Silveira, duly seconded by Giulio Zavolta, and unanimously carried THAT the Committee fund all above indicated projects for a total of $298,360.42 along with both NCE requests for 2020 projects and a contingency fund of $20,000 bringing the total 2021 FY Research Budget to $334,531.62.

<u>Motion 11.5.20 #3</u> **APPROVED**

MOVED BY Galen Pfeiffer, duly seconded by Giulio Zavolta, and unanimously carried THAT the Committee grant authority to the Executive Director and Chairman for inter-item transfers of the Research Budget.

******INFORMATION ONLY******

FROM: COC RESEARCH SUBCOMMITTEE

SUBJECT: REVIEW OF APPROVED 2021 RESEARCH PROJECTS

BACKGROUND: The Full Committee approved the following 2021 Research Projects and Budget at the meeting on December 8, 2020.

Researcher	Project	Amount	Finalized MOU	Paid thus far	% Paid	No Cost Extension
Giulia Marino Louise Ferguson	Timing Ethylene Applications as a Function of Heat Unit Accumulation	$24,470				
Carol Lovatt Elizabeth Fitchtner	Managing Alternate Bearing in Olive with PGRs and Pruning	$27,230				
Giulia Marino Louise Ferguson	Precise Water Management Strategies for Table Olive Orchards in California	$54,303				
J. E. Adaskaveg	Epidemiology and management of olive knot caused by Pseudomonas savastanoi pv.savastanoi	$31,650				
J. E. Adaskaveg	Management of foliar diseases of olive (peacock spot)	$10,000				
Georgia Drakakaki	Characterization of Olive Fruit Abscission Zone in Response to Ethylene Applications and as a Function of Developmental Stage	$64,260				
Jim Stewart	Southern San Joaquin Valley Olive Fruit Fly Monitoring Project	$9,950				
Ernie Simpson	Sacramento Valley Olive Fruit Fly Monitoring Project	$6,500				
Carol Lovatt Elizabeth Fitchtner	Managing Alternate Bearing in Olive with PGRs and Pruning	$9,293	2/14/2020			6/30/2021
Frank Zalom Joanna Fisher	Control of overwintering olive fruit fly using insect pathogenic fungi	$6,878	2/14/2020			6/30/2021
	Contingeny Fund	$ 89,997.00				
	Total	**$334,532**		$0.00		

******INFORMATION ONLY******

FROM: COC RESEARCH SUBCOMMITTEE

SUBJECT: PRESENTATION OF 2021 RESEARCH PROPOSALS

BACKGROUND: At the December 8th Full Committee Meeting, the Full Committee decided they would like to see a second proposal from researcher Dr. Reza Ehsani in regards to a project focused on the design of a shaker better suited for mature trees. Dr. Ehsani is here to present on the second proposal provided in your packet.

For reference, Dr. Ehsani's original proposal is provided on page 19.

Re CALIFORNIA OLIVE COMMITTEE

PROJECT PLAN/RESEARCH GRANT PROPOSAL

Workgroup/Department: School of Engineering – Mechanical Engineering

Project Year: Anticipated Period of Performance: 05/15/2021 – 05/14/2022

Project Title: Combining trunk shaking and canopy shaking for a highly efficient, low-cost olive harvester – Part 2 Mature Trees

Project Leaders: Reza Ehsani (Professor, University of California, Merced, 5200 N. Lake Road, Merced, CA 95343, (209) 228-3613, rehsani@ucmerced.edu)

Cooperators: Louise Ferguson, CE Pomologist, Department of Plant Sciences, UC Davis, Email: lferguson@ucdavis.edu, Phone: (559) 737-3061

Commodity: ________________________________Relevant AES/CE Project No.:

Year Initiated: 2021_Anticipated Duration of Project: one year

Problems and Significance:

Harvesting is the major cost of production for many crops, including olive. Mechanical harvesting of olives was initiated in the US in the 1940s. The main goal was to develop a cost-effective technique to harvest olive fruit for both table and oil extraction (Sola-Guirado et al., 2014). Among all the proposed methods, mechanical shaking has been the most successful approach for fruit removal and machines were commercially available. Different types of trunk, branch, and canopy contact shakers were developed (Jimenez-Jimenez et al., 2015 and Famiani et al., 2014). The efficiency of these shakers was improved with canopy management that limited tree height and formed upright scaffolds. Trunk shakers had lower fruit removal efficiency due to the damping effect of branches (Castro-Garcia et al., 2014 and Ferguson et al., 2014). Besides the lower efficiency, damage to the bark of the trunk and branches causes lowered yield in succeeding years and increased the risk of infestation and disease in the trunks (Jimenez-Jimenez et al., 2015). For other types of shakers, especially canopy shakers, damage to the branches and leaves and final fruit quality issues such as cuts and flesh injury were a problem (Ferguson et al., 2010). This fruit damage reduced market acceptability, especially of green processed table olives. To solve the issues with mechanical harvesting of traditional orchards, Ferguson et al. (2010) suggested modifying the canopy size and shape of conventional trees and mechanical harvester parameters s simultaneously.

Although some olive growers are having some success with trunk shakers, this method has not been widely utilized because olive trees' willowy characteristics prevent the effective transmission of vibrational energy from the trunk to the small distal branches where the fruit is located. To remove fruit with a trunk shaker requires a large amount of energy and extended duration, which can cause tree damage. Also, for some older orchards, the trunk shaker may not be an option due to the size and shape of the trunk and/or canopy.

Engineers at UC Davis developed a prototype canopy contact shaker that was tested with some success and which was very similar to the canopy shaker used to harvest Florida juice oranges. Ehsani's group at UC Merced used an alternative design to develop a 50% lighter canopy contact shaker-based fruit removal system that can accommodate larger trees. This system has shown promising results as well. The UC Merced design was able to produce the maximum shaking energy at the fruit level as opposed to the trunk, and hence, less damage to the tree. However, it

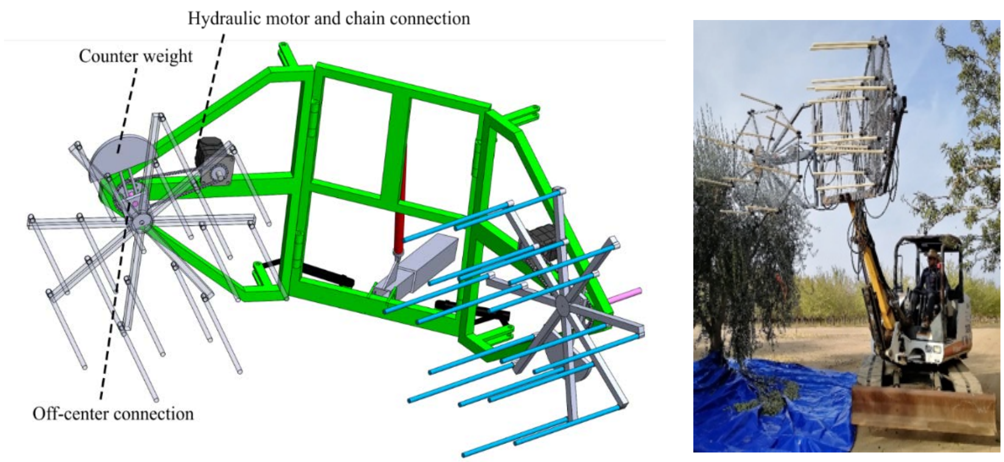


Figure 1. UC Merced fruit removal canopy shaking head

took a longer time to shake each tree.

In part one of this COC funded project, a simultaneous combination of trunk and canopy shaker technologies were tested in 2020. The combined shaking methods demonstrated a higher harvest efficiency compared to using either alone.

In the 2021 project, we propose to build a new prototype harvester combining both trunk and canopy shaker in one machine. We intend to conduct extensive field tests to assess the best shaking parameters, amplitudes and frequencies. These parameters are needed for fine-tuning the machine to achieve the optimal machine capacity.

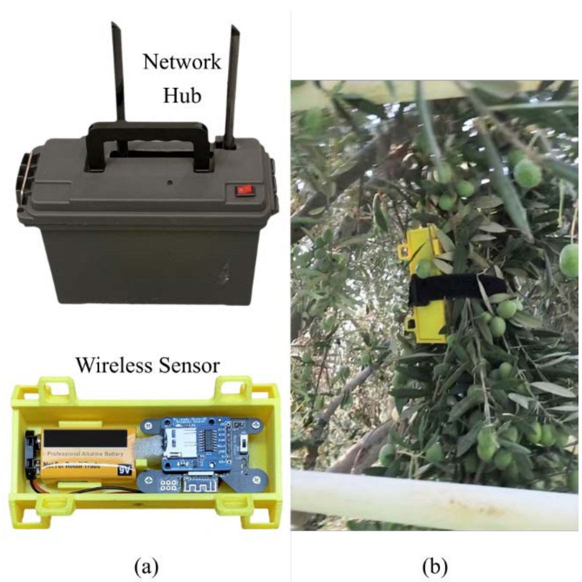


Figure 2. Wireless sensor module and network hub (a) and a wireless sensor module installed on olive branches for data collection (b).

<u>Progress to Date</u>:
This project is the continuation of a previously funded California Olive Committee project.

Merced. Figure 1 shows the UC Merced canopy shaker fruit removal system.

The UC Merced-designed canopy shaker was tested in 2018, 2019 and 2020. To measure and record vibration distribution throughout the canopy, we developed a wireless sensor system consisting of a network hub unit and multiple wireless sensing modules. Each sensing module has a built-in 3D accelerometer, wireless module, storage module and battery. These sensors can record data up to 550 samples per second in each axis. The network hub unit connects wirelessly to all the sensing modules and triggers the data collection procedure (Figure 2).

UC Merced canopy shaker

Figure 1 shows the UC Merced canopy shaker fruit removal system developed in Ehsani's lab. This canopy shaker was tested in 2018 and 2019. To measure and record vibration and force distribution throughout the canopy, a wireless sensor system consisting of a network hub and multiple sensing modules was developed. Each sensing module has a built-in 3D accelerometer, wireless module, battery, and storage unit. The network hub connects wirelessly to all the sensing modules and lets the operator trigger data recording via a smartphone app (Figure 2). Three accelerometer sensors were attached to a tree to monitor tree vibration. One sensor was attached to the tree trunk, one to the main branch, and one to a second smaller branch. Using these sensors, we could compare the acceleration distribution throughout the tree canopy of both the UC Merced's canopy shaker and a trunk shaker harvester. Figure 3 shows the acceleration of each sensor for each of these harvesters when both were shaking a tree simultaneously. The data collected from the canopy shaker (Figure 3) shows that the small-diameter branches vibrate at a higher acceleration than the larger primary branches and trunk. The canopy shaker transmitted more energy to the small branches than to the tree trunk and root system (Figure 4B), potentially producing less tree damage than a trunk shaker. Figure 4A shows the data collected for the trunk shaker. It shows there is much higher acceleration in the trunk than the small branches, indicating the UC Merced canopy shaker applies most of the energy where the fruits are located and, therefore, is more efficient. Compared to trunk shaking, the amount of acceleration (force) decreased by 70% at the tree trunk and 57% at the main branches and increased by 134% at the small branches. Figure 4C shows the results

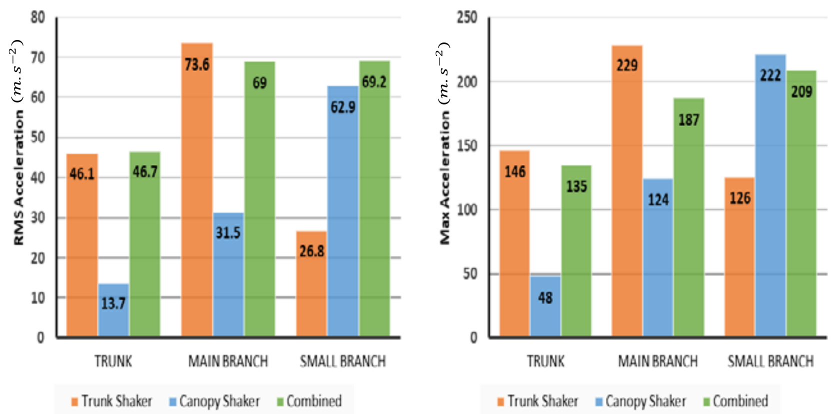


Figure 3. Root mean square of vibration measured at each part of a tree (left) and maximum acceleration produced by the two harvesters at each part of a tree (right).

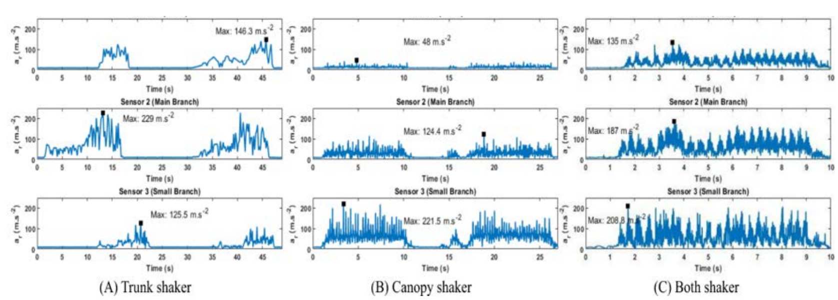


Figure 4. Vibration transmission through tree using (A) trunk shaker, (B) Ehsani's lab canopy shaker and (C) both shaker working at the same time.

of the test in which a tree was shaken using both the canopy shaker and trunk shaker at the same time. Figure 3 shows the root mean square and maximum amplitude of vibration recorded by the sensors on the tree. This figure demonstrates that a combination method of shaking (both trunk and canopy) would more effectively remove fruit in less time. It shows a more uniform distribution of energy throughout the canopy.

Combined shaker experiment

A combination trunk shaker and UC Merced canopy shaker were tested on 33 trees during the 2020 harvest season in Nickels Soils Laboratory orchard Arbuckle, CA). An Orchard Machinery Corporation (OMC) the trunk shaker was used. For each shaker, trunk, and canopy, three different shaking frequencies were chosen. Eleven trials were conducted, including the nine combinations of shaking frequencies (Figure 5), and one trial each using the trunk shaker and UC Merced canopy shakers alone (Table 1). Each trial had three replicates (a total of 33 trees). The canopy shaker was set to a 2″ off-center distance, generating an oscillation with a 4″ amplitude. Rotational speed was set to 100, 150 and 200 rpm for the experiment. The trunk shaker intensity was set to low, medium and high. Shake duration was set to 15 seconds.

Figure 5 Trunk shaker and canopy shaker, shaking an olive tree simultaneously

Table 1. Experiment design for selecting the optimum combined shaking frequency. Each treatment will be replicated three times.

Trunk shaker intensity / Canopy shaker (rpm)	Low	Medium	High
100	Trial-1	Trial-2	Trial-3
150	Trial-4	Trial-5	Trial-6
200	Trial-7	Trial-8	Trial-9

Canopy shaker	Trial-10
Trunk shaker	Trial-11

Tarps were used to collect the mechanically harvested fruit for weighing. An experienced olive harvesting gleaning crew was hired to harvest the fruit remaining on the trees. The manually harvested fruit was weighed and recorded. Harvest efficiency was calculated using equation below.

$$Efficiency = \frac{Mechanically\ harvested\ (lb)}{Manually\ harvested\ (lb) + \ Mechanically\ harvested\ (lb)} \times 100$$

Harvest efficiency for each of 11 trials is shown in Figure 6. Trial 1 through trial 9 used the UC Merced canopy and the OMC trunk shakers simultaneously. Trial 10 used the UCM canopy shaker alone and trial 11 used the OMC trunk shaker alone.

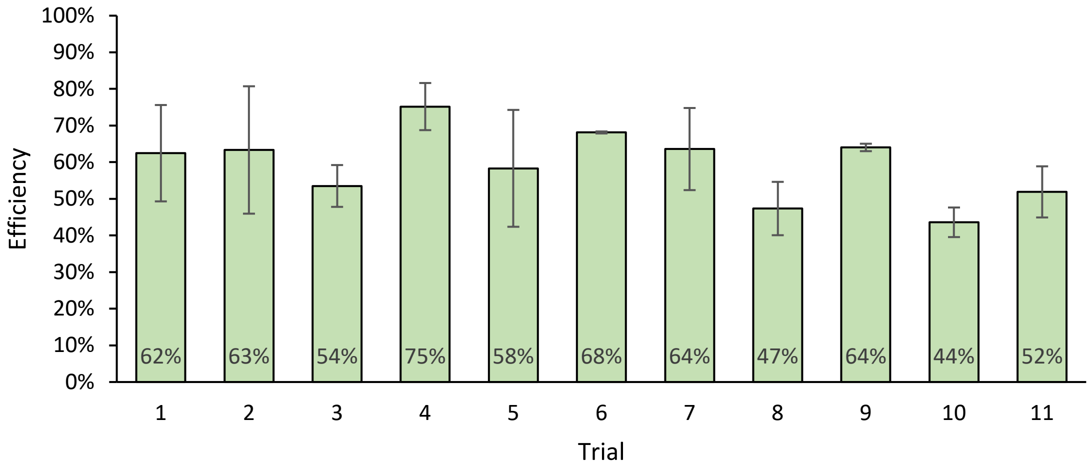


Figure 6 Harvest efficiency for all trials. Trials 1 to 9 were used both canopy shaker and trunk shaker simultaneously, Trial 10 has used UC Merced canopy shaker only and trial 11 has used the OMC trunk shaker.

Figure 6 shows harvest efficiency when using both shakers simultaneously, except for trial 8, all other trials produced better harvest efficiencies compared to using each shaker individually. Figure 7 shows the average harvest efficiency of all three shaking methods. This figure shows the combined shaker method has improved harvest efficiency by 41% and 19% compared to canopy shaker and trunk shaker alone, respectively.

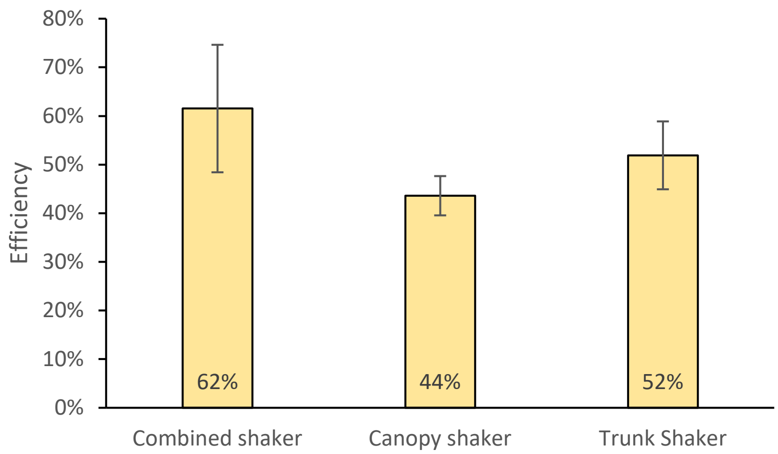


Figure 7 Comparing harvest efficiency of all three methods.

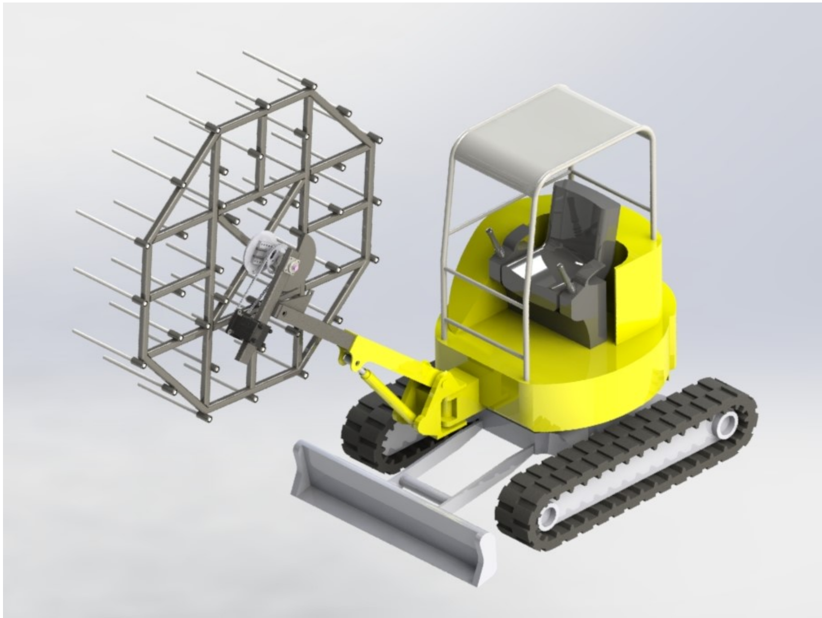


Figure 8. Proposed shaker design that includes a side-mounted canopy shaker.

These results demonstrate harvesting an olive tree using trunk and canopy contact shakers simultaneously will increase harvest efficiency. Among the nine trials using both shakers, trials 4 and 6 had the highest harvest efficiencies, 75% and 68%, respectively. While this concept worked relatively well for small to medium-size trees, it is not suitable for larger mature trees because the shaking head is too small to effectively shake the tree canopy. In this project, we are proposing to design and build a larger shaker head that is suitable for large mature olive trees and test its performance on a growers orchard in combination with a trunk shaker

Objectives:

- Study whether a combination of canopy shaker and trunk shaker is suitable for larger and mature olive trees.
- Find the best shaking parameters (frequency, amplitude, duration) for a combination of trunk shaker and canopy shaker that is suitable for older trees
- To disseminate the integrated knowledge gained through this research.

Experimental Procedures:

The following specific tasks are planned to achieve the above objectives:

Task 1- To design and construct a lightweight but larger size side-mounted canopy shaking head that can be attached to a mini-excavator and can accommodate shaking the canopy of larger olive trees in California. A canopy shaker head design is conceptualized based on field observation (Figure 8). The new side-mounted canopy shaker is designed for larger mature olive trees that have not been trained for the mechanical shaker. In this design, since the shaking head is side-mounted, it is easier for the machine to move between the tree rows. The shaker attachment will allow the machine to go through orchard rows and shake every single tree at the required height.

The design specifications will be based on the average size of larger and mature olive trees that are currently available in California and consultation with local growers and Dr. Ferguson. This newly designed canopy shaker will work with an existing trunk shakers that are currently being used by some of the olive growers for harvesting larger trees. We expect that the combination of these two machines will be more efficient in removing fruits from large olive trees.

Task 2- Conduct a series of field tests at one of the collaborating growers and varying frequency and amplitude of the canopy shaker to determine the optimal values for each system as well as for the combination.

Field Trial procedure:

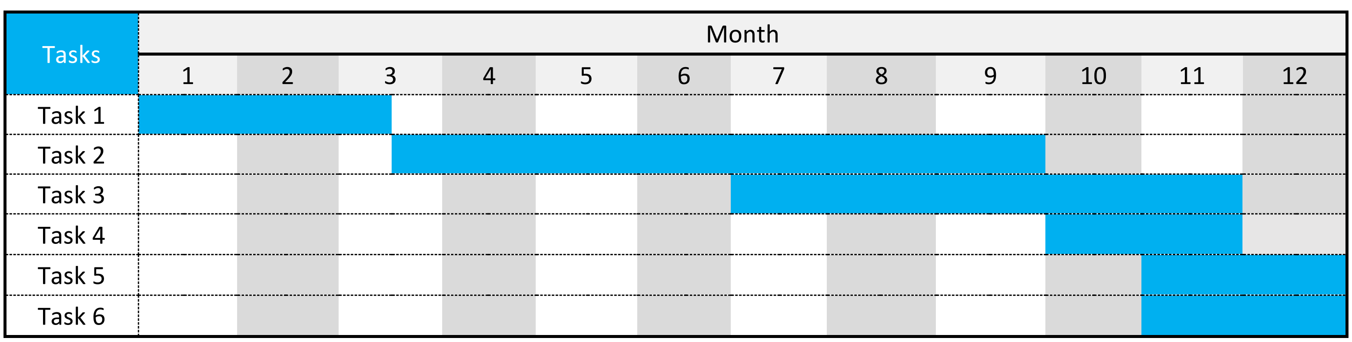
Extensive field tests will be conducted in a commercial olive orchard. COC will help us to locate a collaborating grower for this project.

Two shaking frequencies for the canopy shaker and trunk shaking component will be tested and evaluated. Each trial will be tested on three trees (Table 2). These trials will be replicated three times. The best frequency combination will be chosen.

Table 2. Experiment design for selecting the optimum combined shaking frequency. Each treatment will be replicated three times

Trunk shaker / Canopy shaker	Freq.1	Freq.2
Freq.1	Trial-1	Trial-2
Freq.2	Trial-3	Trial-4

Project Timeline:



BUDGET REQUEST: Reza Ehsani

Budget Year: 2021 Funding Source: COC

Labor:	**Line 1**
Salary	
One Graduate Student Researcher	
Full-Time during Academic Terms and 50% during Summer Term	$29,373
1.3% Benefit Rate	$382
Subtotal 1	**Line 1 Subtotal $29,755**

Supplies:	**Line 2**
Supplies: Estimates for hauling the mechanical harvester to the field, raw materials for fabrication, hydraulic components, hosing and hydraulic motors, hydraulic valves, renting a trunk shaker, consumable shop supplies, and supplies for field data collection	
Subtotal 2	**Line 2 subtotal $16,250**

Travel:	**Line 3**
Vehicle Use: Truck use for three weeks for field trials and local travel	$500
Subtotal 3	**Line 3 subtotal $500.00**

Tuition/Fees:	**Line 4**
Graduate student fees and tuition for the 9-month academic year for a non-resident graduate student. University policy requires the inclusion of tuition/fee remission for graduate student researchers employed 25% time or more during the academic year. These costs are based on published University rates with a 10% increase.	$15,792
Subtotal 4	**Line 4 Subtotal $15,792**
Total of lines 1 through 4 above	**(Line 5) $62,297**
Modified Total Direct Cost	**(Line 6) $62,297**
UCD/ANR/UCR Overhead on MTDC (Line 6)	**(Line 7) $7,700**
Total to Primary PI)	**(Line 5 + 7) $69,997**
TOTAL BUDGET REQUEST	**$69,997**

PRIMARY PI SIGNATURE PAGE: UNIVERSITY OF CALIFORNIA

Reza J Ehsani	12/16/2020
Originator's Signature	Date
	12/16/2020
Department Chair/County Director	Date
Liaison Officer	Date

CALIFORNIA OLIVE COMMITTEE

PROJECT PLAN/RESEARCH GRANT PROPOSAL

Workgroup/Department: School of Engineering – Mechanical Engineering

Project Year: Anticipated Period of Performance: 05/15/2021 – 05/14/2022

Project Title: Combining trunk shaking and canopy shaking for a highly efficient, low-cost olive harvester – Part 2

Project Leaders: Reza Ehsani (Professor, University of California, Merced, 5200 N. Lake Road, Merced, CA 95343, (209) 228-3613, rehsani@ucmerced.edu)

Cooperators: Louise Ferguson, CE Pomologist, Department of Plant Sciences, UC Davis, Email: lferguson@ucdavis.edu, Phone: (559) 737-3061

Commodity: ________________________________Relevant AES/CE Project No.:

Year Initiated: 2021_Anticipated Duration of Project: one year

Problems and Significance:

Harvesting is the major cost of production for many crops including olive. Mechanical harvesting of olives was initiated in the US in the 1940s. The main goal was to develop a cost-effective technique to harvest olive fruit for both table and oil extraction (Sola-Guirado et al., 2014). Among all the proposed methods, mechanical shaking has been the most successful approach for fruit removal and machines were commercially available. Different shakers, trunk, branch, and canopy contact, were developed (Jimenez-Jimenez et al., 2015 and Famiani et al., 2014). The efficiency of these shakers was improved with canopy management that limited tree height and formed upright scaffolds. Trunk shakers had lower fruit removal efficiency due to the damping effect of branches (Castro-Garcia et al., 2014 and Ferguson et al., 2014). Besides the lower efficiency, damage to the bark of the trunk and branches causes lowered yield in succeeding years and increased the risk of infestation and disease in the trunks (Jimenez-Jimenez et al., 2015). For other types of shakers, especially canopy shakers, damage to the branches and leaves, and final fruit quality issues such as cuts and flesh injury were a problem (Ferguson et al., 2010). This fruit damage reduced market acceptability, especially of green processed table olives. To solve the issues with mechanical harvesting of traditional orchards, Ferguson et al. (2010) suggested modifiying the canopy size and shape of conventional trees and mechanical harvester parameters s simultaneously.

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Engineers at UC Davis developed a prototype canopy contact shaker that was tested with some success and which was very similar to the canopy shaker used to harvest Florida juice oranges. Ehsani's group at UC Merced used an alternative design to develop a 50% lighter canopy contact shaker-based fruit removal system that can accommodate larger trees. This system has shown promising results as well. The UC Merced design was able to produce the maximum shaking energy at the fruit level as opposed to the trunk, and hence, less damage to the tree. However, it took a longer time to shake each tree.

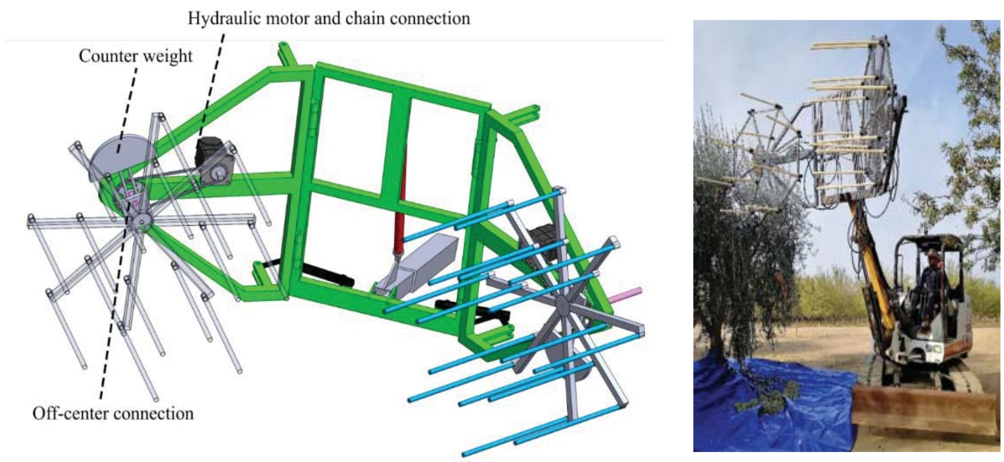

Figure 1. UC Merced fruit removal canopy shaking head

In part one of this COC funded project a simultaneous combination of trunk and canopy shaker technologies were tested in 2020. The combined shaking methods demonstrated a higher harvest efficiency compared to using either alone.

In the 2021 project, we propose to build a new prototype harvester combining both trunk and canopy shaker in one machine. We intend to conduct extensive field tests to assess the best shaking parameters, amplitudes and frequencies. These parameters are needed for fine tuning the machine to achieve the optimal machine capacity.

(a) (b)

Figure 2. Wireless sensor module and network hub (a) and a wireless sensor module installed on olive branches for data collection (b).

<u>Progress to Date</u>:

This project is the continuation of a previously funded California Olive Committee project.

Merced. Figure 1 shows the UC Merced canopy shaker fruit removal system.

The UC Merced-designed canopy shaker was tested in 2018, 2019 and 2020.. To measure and record vibration distribution throughout the canopy, we developed a wireless sensor system consisting of a network hub unit and multiple wireless sensing modules. Each sensing module has a built-in 3D accelerometer, wireless module, storage module and a battery. These sensors can record data up to 550 samples pes second in each axis. The network hub unit connects wirelessly to all the sensing modules and triggers the data collection procedure (Figure 2).

UC Merced canopy shaker

Figure 1 shows the UC Merced canopy shaker fruit removal system developed in Ehsani's lab. This canopy shaker was tested in 2018 and 2019. To measure and record vibration and force distribution throughout the canopy, a wireless sensor system consisting of a network hub and multiple sensing modules was developed. Each sensing module has a built-in 3D accelerometer, wireless module, battery, and storage unit. The network hub connects wirelessly to all the sensing modules and lets the operator trigger data recording via a smartphone app (Figure 2) Three accelerometer sensors were attached to a tree to monitor tree vibration. One sensor was attached to the tree trunk, one to the main branch, and one to a second smaller branch. Using these sensors, the we could compare the acceleration distribution throughout the tree canopy of both the UC Merced's canopy shaker and a trunk shaker harvester. Figure 3 shows the acceleration of each sensor for each of these harvesters when both were shaking a tree simultaneously. The data collected from the canopy shaker (Figure 3) shows that the small-diameter branches vibrate at a higher acceleration than the larger primary branches and trunk. The canopy shaker transmitted more energy to the small branches than to the tree trunk and root system (Figure 4B), potentially producing less tree damage than a trunk shaker. Figure 4A shows the data collected for the trunk shaker. It shows there is much higher acceleration in the trunk than the small branches, indicating the UC Merced canopy shaker applies most of the energy where the fruits are located, and, therefore is more efficient. Compared to trunk shaking, the amount of acceleration (force) decreased by 70% at the tree trunk and 57% at the main branches and increased by 134% at the small branches. Figure 4C shows

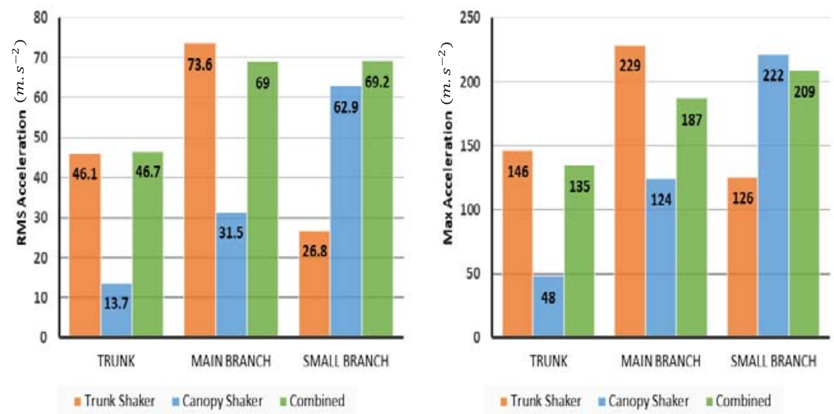

Figure 3. Root mean square of vibration measured at each part of a tree (left) and maximum acceleration produced by the two harvesters at each part of a tree (right).

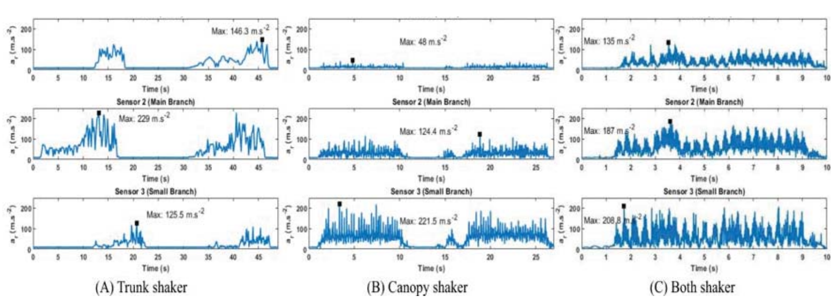

Figure 4. Vibration transmission through tree using (A) trunk shaker, (B) Ehsani's lab canopy shaker and (C) both shaker working at the same time.

the results of the test in which a tree was shaken using both the canopy shaker and trunk shaker at the same time. Figure 3 shows the root mean square and maximum amplitude of vibration recorded by the sensors on the tree. This figure demonstrates that a combination method of shaking (both trunk and canopy) would more effectively removr fruit in less time. It shows a more uniform distribution of energy throughout the canopy.

Combined shaker experiment

A combination trunk shaker and UC Merced canopy shaker was tested on 33 trees during the 2020 harvest season in Nickels Soils Laboratory orchard Arbuckle, CA). An Orchard Machinery Corporation (OMC) the trunk shaker was used. For each shaker, trunk and canopy, three different shaking frequencies was chosen. Eleven trials were conducted including the nine combinations of shaking frequencies (Figure 5), and one trial each using the trunk shaker and UC Merced canopy shakers alone (Table 1). Each trial had three replicates (a total of 33 trees). The canopy shaker was set to a 2″ off-center distance, generating an oscillation with a 4″ amplitude. Rotational speed was set to 100, 150 and 200 rpm for the experiment. The trunk shaker intensity was set to low, medium and high. Shake duration was set to 15 seconds.

Figure 5 Trunk shaker and canopy shaker, shaking an olive tree simultaneously

Table 1. Experiment design for selecting the optimum combined shaking frequency. Each treatment will be replicated three times.

Trunk shaker intensity / Canopy shaker (rpm)	Low	Medium	High
100	Trial-1	Trial-2	Trial-3
150	Trial-4	Trial-5	Trial-6
200	Trial-7	Trial-8	Trial-9
Canopy shaker		Trial-10	
Trunk shaker		Trial-11	

Tarps were used to collect the mechanically harvested fruit for weighing. An experienced olive harvesting gleaning crew was hired to harvest the fruit remaining on the trees. The manually harvested fruit was weighed and recorded. Harvest efficiency was calculated using equation below.

$$Efficiency = \frac{Mechanically\ harvested\ (lb)}{Manually\ harvested\ (lb) + \ Mechanically\ harvested\ (lb)} \times 100$$

Harvest efficiency for each of 11 trials is shown in Figure 6. Trial 1 through trial 9 used the UC the Merced canopy and the OMC trunk shakers simultaneously. Trial 10 used the UCM canopy shaker alone and trial 11 used the OMC trunk shaker alone.

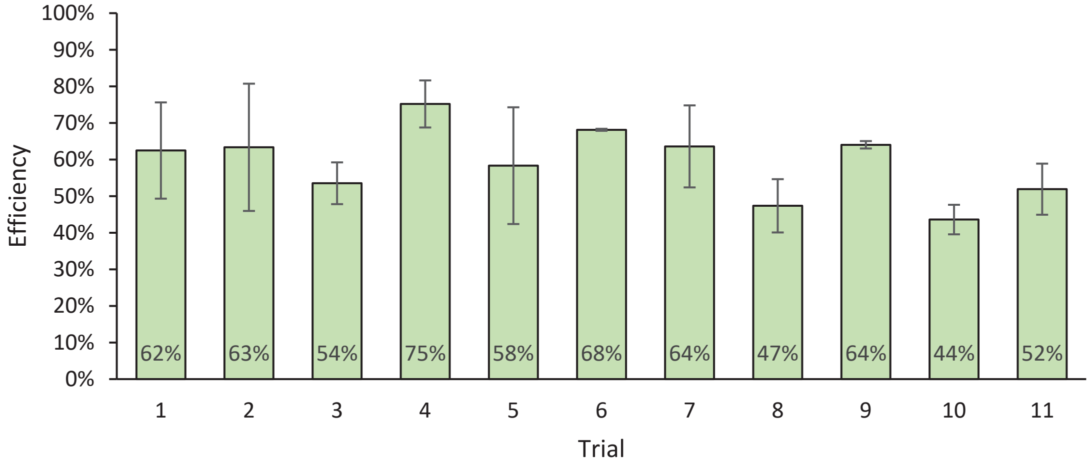

Figure 6 Harvest efficiency for all trials. Trials 1 to 9 were used both canopy shaker and trunk shaker simultaneously, Trial 10 has used UC Merced canopy shaker only and trial 11 has used the OMC trunk shaker.

Figure 6 shows using both shakers simultaneously, except for trial 8, produced better harvest efficiencies compared to using shaker individually. Figure 7 shows the average harvest efficiency of all three shaking methods. This figure shows the combined shaker method has improved harvest efficiency by 41% and 19% compared to canopy shaker and trunk shaker alone, respectively.

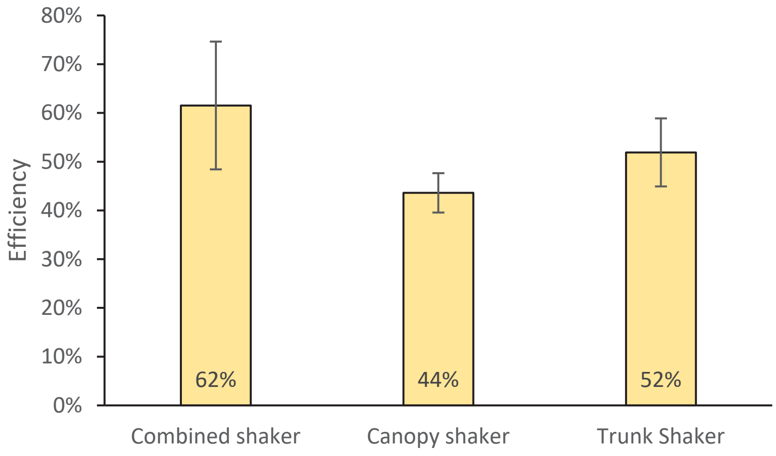

Figure 7 Comparing harvest efficiency of all three methods.

Figure 8. Proposed shaker design that includes both canopy shaker and trunk shaker components.

These results demonstrate harvesting an olive tree using trunk and canopy contact shakers simultaneously will increase harvest efficieny. Among the nine trials using both shakers, trials 4 and 6 had the highest harvest efficiencies, 75% and 68% respectively. Vibration data and lab quality results will be presented in the final report. A modified canopy shaker design was discussed and conceptualized based on field observation and will also be proposed.

Objectives:

The goal of this study is to increase the profitability of table olive by reducing harvesting costs using mechanical harvesting machines. The specific objectives are as follows:

- **Objective 1**: Design and build a combined trunk and canopy shaker machine specifically for table olives based on the tree and fruit properties.
- **Objective 2**: Study the effect of pruning on harvest efficiency.
- **Objective 3:** To disseminate the integrated knowledge gained through this research.

Experimental Procedures:

To achieve the objectives, the following tasks are planned:

Task 1: Design a combined shaker machine for table olive harvesting
Task 2: Build the designed combined shaker
Task 3: Evaluate the performance of the machine in the field
Task 4: Study whether pruning would increase harvest efficiency or not.
Task 5: Write the final report and publish the results.

The proposed trunk shaker includes both canopy and trunk shaking components (Figure 8). It will be pulled by a tractor in the field and be powered by the tractor's hydraulic source. Two of these machines will be built; both will have a canopy shaking component but only one will have the trunk shaking component. The two shakers will compress and harvest a tree from the opposite sides simultaneously with the trunk shaker from one side only.

Field Trial procedure:

The proposed shakers will be tested in Nickels Soils Laboratory olive orchard (Arbuckle, CA) during harvest 2021. Two shaking frequencies for the canopy shaking component and trunk shaking component will be tested and evaluated. Each trial will be tested on three trees (Table 2).

Table 2. Experiment design for selecting the optimum combined shaking frequency. Each treatment will be replicated three times

Canopy shaker \ Trunk shaker	Freq.1	Freq.2
Freq.1	Trial-1	Trial-2
Freq.2	Trial-3	Trial-4

The best frequency combination will be chosen and tested in a second field test to identify the effect of pruning on harvest efficiency (Table 3). These trials will be replicated five times.

In a separately submitted coordinated experiment the 4 frequency combination above will repeated on 3 trees receiving an ethephon spray.

Table 3. Experiment design for evaluating effect of pruning on harvest efficiency.

Unpruned Olive trees	Trial-5
Pruned Olive trees	Trial-6

Project Timeline:

Tasks	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Task 1	■	■	■									
Task 2			■	■	■	■	■	■	■			
Task 3							■	■	■	■	■	
Task 4										■	■	
Task 5											■	■
Task 6											■	■

BUDGET REQUEST: Reza Ehsani

Budget Year: 2021 Funding Source: COC

Labor:	**Line 1**
Salary	
One Graduate Student Researcher	
Full-Time during Academic Terms and 50% during Summer Term	$29,373
1.3% Benefit Rate	$382
Subtotal 1	**Line 1 Subtotal $29,755**

Supplies:	**Line 2**
Supplies: Estimates for hauling the mechanical harvester to the field ($3,000), raw materials for fabrication, hydraulic components, hosing and hydraulic motors, hydraulic valves ($12,000), consumable shop and welding supplies, supplies for field data collection supplies ($1,750)	
Subtotal 2	**Line 2 subtotal $16,750**

Travel:	**Line 3**
Vehicle Use: Truck use for two weeks for field trials ($190.00/week)	$0
For work site and COC meetings	$0
Dr. Ferguson travel charges, for work site and COC meetings	$0
Subtotal 3	**Line 3 subtotal $0.00**

Tuition/Fees:	**Line 4**
Graduate student fees and tuition for the 9-month academic year for a non-resident graduate student. University policy requires the inclusion of tuition/fee remission for graduate student researchers employed 25% time or more during the academic year. These costs are based on published University rates with a 10% increase.	$15,793
Subtotal 4	**Line 4 subtotal $15,793**
Total of lines 1 through 4 above	**(Line 5) $62,297**
Modified Total Direct Cost	**(Line 6) $62,297**
UCD/ANR/UCR Overhead @ 11% IDC on MTDC (Line 6)	**(Line 7) $7,700**
Total to Primary PI)	**(Line 5 + 7) $69,997**
TOTAL BUDGET REQUEST	**$69,997**

PRIMARY PI SIGNATURE PAGE: UNIVERSITY OF CALIFORNIA

Reza J Ehsani _10/30/2020__

Originator's Signature Date

Jue C. Sun Digitally signed by Jue C. Sun Date: 2020.10.30 11:19:06 -07'00'

Director Sponsor Project Office Date

Contracts and Grants Officer Date

****ACTION REQUIRED****

FROM: COC RESEARCH SUBCOMMITTEE

SUBJECT: APPROVAL OF 2021 RESEARCH PROJECT

BACKGROUND: At the December 8th Full Committee the Committee approved a 2021 Research Budget at $244,534.62 with a contingency fund of $89,997. The Committee also delegated the authority to the Research Subcommittee to make the final decision on whether or not to fund Dr. Ehsani's 2021 project.

1. Combining trunk shaking and canopy shaking for a highly efficient, low-cost olive harvester–Part 2 Mature Trees
FISCAL IMPACT: $69,997

2. Combining trunk shaking and canopy shaking for a highly efficient, low-cost olive harvester–Part 2
FISCAL IMPACT: $69,997