

CALIFORNIA AVOCADO COMMISSION

PROJECT PLAN - RESEARCH GRANT PROPOSAL

Proposal Budget Requested: \$36,996

CAC Fiscal Year: 2008 - November 1, 2007 - October 31, 2008

Anticipated Duration of Project: 4 years

This project is: Ongoing, year 2 of 4

Project Title: **PGR II - Strategies to increase fruit size of 'Hass' avocado**

Name of Primary Researcher: Carol J. Lovatt

Address: Department of Botany and Plant Sciences

Telephone: 951-827-4663

Fax: 951-827-4437

Email: carol.lovatt@ucr.edu

Name of Research Institution: University of California, Riverside

Name(s) of Supporting Research Staff (including, if different from preceding, address, telephone, fax and email):

Yusheng Zheng, Assistant Specialist

Current vitae for all research participants. Please send one vitae per year, not one per project.

Per instructions, Carol Lovatt's and Yusheng Zheng's CVs have been sent in a separate file and not attached to each project.

Please provide a list of relevant published research.

Please see Attachment 1.

Provide a review of literature relevant to this research project.

Please see Attachment 2.

Indicate to which, if any, of the listed industry research priorities the proposal relates. (NOTE: Listed industry research priorities are intended as a guideline. Proposals addressing other areas will not be excluded from the review and funding process.)

This proposal addresses the objective of the California avocado industry to develop and implement research programs that lead to increased grower profitability. The proposed research addresses the research priority for evaluating commercial plant growth regulators on vegetative growth, flowering, fruit set, fruit size and yield.

Provide a review of the literature relevant to the research project.

Competition from Mexico, Dominican Republic, Chile and South Africa requires that the California avocado industry not only increase production per acre, but also increase fruit size to remain profitable. Funds are being sought for additional research with three promising strategies that were identified in a previous project funded by the California Avocado Commission with the goal of obtaining the efficacy data required by Joe Vandepuete, Ph.D., Associate Environmental Research Scientist, California Environmental Protection Agency, Department of Pesticide Regulation, Division of Registration and Health Evaluation, in considering the addition of a PGR use for avocado to an existing PGR label. The efficacy data can be from individual tree replicates in a randomized complete block design of 2 to 4 years duration. He does not require results from large acre-block trials. Results from at least two sites representing the diversity of avocado acreage in California are required. Treatment effects must be statistically significant at the 5% level on an annual basis or when averaged across years (repeated measures analysis) or on a cumulative basis to compensate for alternate bearing. A PGR treatment that is specific for an on- or off-crop is acceptable. For PGR treatments that are effective specifically in an on- or off-crop year, 3 to 4 years of yield data may be required to obtain statistically significant data for the two on- or two off-crop years, respectively. However, for the intended use, i.e., annually, for on-crop years etc., the “label rate needs to be efficacious consistently.” Since we are only dealing with the Hass cultivar, the range in PGR concentration that is efficacious will be narrow. We need to demonstrate a dose response but only one dose needs to be statistically different from the untreated control. Funding is sought to obtain efficacy data in a second orchard and the dose response data for the three strategies to increase fruit size. The three strategies that increase the yield of large size fruit proposed for further testing include: (i) 6-benzyladenine, 25 mg/L, applied at anthesis; (ii) GA₃, 25 mg/L, applied in mid-July followed by prohexadione-Ca, 125 mg/L, 30 days later (mid-August); and (iii) GA₃, 25 mg/L, applied end of June – beginning of July (Tables 1 and 2). 6-Benzyladenine, 25 mg/L, applied at anthesis or GA₃, 25 mg/L, applied in mid-July followed by prohexadione-Ca, 125 mg/L, 30 days later (mid-August) increase the kg and number of large fruit of packing carton sizes 40 and 36 and the combined pool of 40+36+32 as 3-year average and 3-year cumulative yield compared to the control (Tables 1 and 2). Both treatments significantly reduced the kilograms and number of small size fruit (packing carton size 70) compared to the control, but neither treatment reduced total yield (Tables 1 and 2). GA₃, 25 mg/L, applied end of June – beginning of July increases total yield as kg and number of fruit per tree and increases yield of commercially valuable fruit of packing carton sizes 60+48+40 as kg and number of fruit per tree. The effects of GA₃ are only statistically significant for the on-crop year. However, the effects of GA₃ on total yield and yield of large size fruit are statistically

significant when averaged across both the on- and off-crop years and as 2-year cumulative yield (Table 3).

Provide a brief summary of how you believe this project is responsive to the indicated priority, and how it supports industry objectives, expectations and vision.

The proposed research supports the objectives, expectations and vision of the California avocado industry of increasing grower profitability. Limited research has been conducted on the use of foliar-applied plant growth regulators in avocado production. This is especially true in California. Over the past 5 years, we have gained experience regarding the response of the ‘Hass’ avocado to several key commercial PGRs applied at specific stages of tree phenology. We now have data from one commercial avocado orchard that successfully demonstrate the efficacy of properly timed applications of (i) 6-benzyladenine, 25 mg/L, applied at anthesis; (ii) GA₃, 25 mg/L, applied in mid-July followed by prohexadione-Ca, 125 mg/L, 30 days later (mid-August); and (iii) GA₃, 25 mg/L, applied end of June – beginning of July to increase fruit size (Tables 1 and 2). The next step is to demonstrate that these results are reproducible in a second avocado orchard representing a different avocado growing area of the state and that the yield of large size fruit responds incrementally to increases in dose.

Provide research summary indicating how research will be conducted (design/methodology), hypotheses or research questions to be addressed, and any other information you believe should be taken into account in review of this proposal (include here milestones against which you expect research will be evaluated at quarterly intervals. Note that research will be rigorously evaluated for progress, cost efficiency and quality of results. Written quarterly status reports (see attached form) will be required for all research funded, and continued funding will be contingent upon satisfactory progress. Similar annual evaluations will be conducted for any approved multi-year research projects.)

The specific goal of the proposed research is to obtain the efficacy data necessary to add a PGR use for avocado to an existing PGR label. To achieve this goal, the specific objectives of the proposed research are (1) to demonstrate that the ability of the three strategies to increase fruit size is reproducible in a second avocado orchard representing a different avocado growing area of California and (2) to demonstrate that the yield of large size fruit responds incrementally to increases in PGR dose.

To meet objective 1, (i) 6-benzyladenine, 25 mg/L, will be applied at anthesis; (ii) GA₃, 25 mg/L, will be applied in mid-July followed by prohexadione-Ca, 125 mg/L, 30 days later (mid-August); and (iii) GA₃, 25 mg/L, will be applied end of June – beginning of July. This is the first experiment in which the treatment of GA₃, 25 mg/L, applied end of June – beginning of July and the treatment of GA₃, 25 mg/L, applied in mid-July followed by prohexadione-Ca, 125 mg/L, 30 days later (mid-August) will be tested in the same orchard for comparison. It is important to determine if GA₃, 25 mg/L, applied end of June – beginning of July is equally effective as GA₃, 25 mg/L, applied in mid-July followed by prohexadione-Ca, 125 mg/L, 30 days later (mid-August), since a strategy requiring a single PGR would be more cost-effective than one requiring

two PGRs. In addition, we plan to also test the efficacy of applying (*iv*) 6-benzyladenine, 25 mg/L, at anthesis and again at the end of July – beginning of August. Treatment (*v*) is the untreated control. The proposed treatments are consistent with knowledge that we have gained that July is the period of “June” drop for the current crop (Garner, 2004), period of rapid N uptake by mature fruit from the previous spring bloom (Rosecrance and Lovatt, personal communication), and development of the summer vegetative flush, which contributes significantly more inflorescences during the return bloom than the spring flush shoots such that reduced summer vegetative shoot growth during the on-crop year results in the following off-year bloom and crop (López-Jiménez and Lovatt, personal communication), and that August is the period of exponential increase in fruit size for the current crop and abscission of mature fruit (Garner, 2004), and inflorescence initiation for next year’s crop (Salazar-García et al., 1998). To meet objective 2, strategies that successfully (significant at the 5% level) increase the yield of large size fruit in this second orchard for two consecutive harvests or as the 2-year average or 2-year cumulative yield compared to the untreated control will be included in a new experiment to demonstrate dose response.

All objectives will be met using bearing ‘Hass’ avocado trees in a commercial orchard. Yield (kg/tree), fruit size distribution (pack out) and fruit quality of 100 randomly selected fruit, including seed size and fruit length to width ratio, will be determined at harvest. Leaves will be collected in September for nutrient analysis (Albion Laboratories). The experimental design will be a randomized complete block with 20 individual tree replicates per treatment. There will be buffer trees between treated trees and buffer rows between treated rows.

All data will be statistically analyzed by analysis of variance using SAS at $P = 0.05$.

Provide a brief summary of how work contemplated by this proposal will enhance what is already known about the topic. Indicate here how the proposed project will complement or can be integrated with other research.

The research proposed herein will provide a set of data needed for adding a PGR use for avocado to an existing PGR label. In addition, it will advance our understanding of the interaction of PGRs with the ‘Hass’ avocado and ‘Hass’ tree phenology, physiology and fruit development.

Provide a statement of objectives and a schedule of expected accomplishments for the funded year (November 1, 2007-October 31, 2008).

Research to meet objective 1 was initiated in year 1 and will be repeated in year 2. The results for two harvests are necessary before proceeding to objective 2. Objective 2 requires a large number of trees due to the need to apply multiple concentrations of each PGR, or PGR combination being tested, while maintaining 20 individual tree replications. Thus, Objective 2 will not be initiated for any PGR until we are sure of its efficacy from the results obtained in meeting objective 1. Research to meet objective 2 is currently planned for initiation in year 3. The project will be completed in year 4, unless the DPR requires a second set of dose response data.

Indicate expected duration of project:

We are requesting funding for 3 crop years (4 funding years).

2007-08 PROJECT BUDGET

Salaries & Benefits:

Project Leader: Carol Lovatt	0
Assistant Specialist Yusheng Zheng (@ \$3,129/mo., 25% x 10 mo., 50% x 1 mo, plus \$3,223/mo., 50% x 1 mo.	10,999
Laboratory Assistant: TBA (\$12.57/h x 60 h/mo. x 11 mos., plus 1 mo. @ \$12.95/h x 60 h/mo. to provide help with treatment applications, data collection, and harvest)	9,073
SRAs:	0
Benefits: YZ 37%	4,069
TBA 44%	3,992
Subtotal:	28,133
Supplies/Expenses: Nutrient analysis of 100 samples @ \$35 per sample, field supplies for application and harvest	3,500
Equipment:	0
Operating Expenses:	0
Travel: 12 roundtrips to Santa Paula @ 268 x \$0.41/mi. = \$1,319 48-car days x \$25/day = \$1,200 36-man days per diem x \$79/day = \$2,844	5,363
Other:	0
Total:	36,996

Approximate total support funds for this project expected from other sources (include in kind contributions or other "soft money"; indicate source of all funds, in kind or otherwise)

I have a grower cooperater, Gus Gunderson of Limoneira Ranch, who is willing to absorb the expense of destroying the fruit in order to obtain a PGR strategy that will increase fruit size. This is a considerable amount of money.

Indicate whether support funds are:

CAC payment/Disbursement Schedule is quarterly. (If 35% or more of project costs accrue at the front end of the project, please so indicate. A minimum of 20% of approved funding will be withheld pending receipt and approval of final report.)

<u>Dates</u>	<u>Amounts</u>
January 31, 2008	\$7,399
April 30, 2008	\$7,399
July 31, 2008	\$7,399
October 31, 2008	\$7,399

The remaining 20% (\$7,400) due upon receipt of the final report for year 2 on October 31, 2008.

Is satisfactory execution/completion of research project(s) contingent upon receiving support funding *in addition to* CAC funding?

No

Projected budget for FY 07-08 ~\$ 35,900 08-09 ~\$42,000 09-10 ~\$37,000

All approved researchers will be required to sign a CAC Research Agreement for **each year CAC funding is provided.**

Signature (Project Leader): _____

Date: _____

Approved By:

(Organization's Authorized Representative): _____

Date: _____

CALIFORNIA AVOCADO COMMISSION Approval:

Tom Bellamore, Corporate Counsel/Senior Vice President

Date

ATTACHMENT 1

- Salazar-García, S., L.E. Cossio-Vargas, I.J.L. González-Durán and C.J. Lovatt.** 2007. Foliar- fruit applied GA₃ advances maturity and allows off-season harvest of 'Hass' avocado. *HortScience* 42:257-261.
- Salazar-García, S., L.E. Cossio-Vargas, C.J. Lovatt, I.J.L. González-Durán, and M.H. Pérez-Barraza.** 2007. Crop load affects vegetative growth flushes and shoot age influences irreversible commitment to flowering of 'Hass' avocado. *HortScience* 41:1541–1546.
- Violi, H.A., K.K. Treseder, J.A. Menge, S.F. Wright, and C.J. Lovatt.** 2007. Density dependence and interspecific interactions between arbuscular mycorrhizal fungi mediate plant growth, glomalin production, and sporulation. *Can. J. Bot.* 85:63–75.
- Salazar-García, S., L.E. Cossio-Vargas, I.J.L. González-Durán, and C. J. Lovatt.** 2006. Effect of canopy sprays with plant bioregulators on 'June fruit drop', yield and fruit size of 'Hass' avocado. *Acta Hort.* 727:197-202.
- Lovatt, C.J.** 2006. Plant growth regulators for avocado production. *Calif. Avocado Soc. Yrbk.* 88:81–91.
- Lovatt, C.J. and G. Witney.** 2001. Nitrogen Fertilization of the 'Hass' avocado in California. *AvoResearch* 1(3):1-4,11.
- Lovatt, C.J.** 2001. Properly timed soil-applied nitrogen fertilizer increases yield and fruit size of 'Hass' avocado. *J. Amer. Soc. Hort. Sci.* 126:555–559.
- Salazar-García, S. and C.J. Lovatt.** 2000. Use of GA₃ to manipulate flowering and yield of the 'Hass' avocado. *J. Amer. Soc. Hort. Sci.* 125:25-30.
- Lovatt, C. J.** 1999. Timing citrus and avocado foliar nutrient applications to increase fruit set and size. *HortTechnology* 9:607-612.
- Salazar-García, S. and C.J. Lovatt.** 1999. Winter trunk injections of gibberellic acid altered the fate of 'Hass' avocado buds: Effects on inflorescence type, number, and rate of development. *J. Hort. Sci. and Biotech.* 74: 69-73.
- Salazar-García, S., E. M. Lord, and C. J. Lovatt.** 1999. Inflorescence development of the 'Hass' avocado: Commitment to flowering. *J. Amer. Soc. Hort. Sci.* 124: 478-482.
- Bertling, I. and C. J. Lovatt.** 1998. Uptake of PGRs into determinate versus indeterminate inflorescences of the 'Hass' avocado (*Persea americana* Mill.). *In Proceedings, Third World Avocado Congr., Tel Aviv, Israel, October 21-27, 1995.* *Acta Hort.* 1: 3-6.
- Jaganath, I. and C. J. Lovatt.** 1998. Efficacy studies on prebloom canopy applications of boron and/or urea to 'Hass' avocado. *In Proceedings, Third World Avocado Congr., Tel Aviv, Israel, October 21-27, 1995.* *Acta Hort.* 1: 181-184.
- Lovatt, C. J.** 1998. Successful use of foliar applications of essential mineral nutrient elements to increase fruit set and yield of citrus and avocado. *Subtropical Fruit News* 6: 21-24. [Invited contribution]
- Lovatt, C. J.** 1998. Nitrogen nutrition of the 'Hass' avocado--*Where does all the N go?* *In Proceedings, Third World Avocado Congr., Tel Aviv, Israel, October 21-27, 1995.* *Acta Hort.* 1: 152-159. [Invited contribution]

- Lovatt, C. J.** 1998. November or April soil-applied nitrogen fertilizer increases Hass avocado yield and fruit size. *California Avocado Grower*, October 1998(4): 4-7. [Invited contribution]
- Salazar-Garcia, S. and C. J. Lovatt.** 1998. GA₃ application alters flowering phenology of 'Hass' avocado. *J. Amer. Soc. Hort. Sci.* 123: 791-797.
- Salazar-Garcia, S. and C. J. Lovatt.** 1998. Effect of gibberellic acid on inflorescence phenology of the 'Hass' avocado. *In Proceedings, Third World Avocado Congr.*, Tel Aviv, Israel, October 21-27, 1995. *Acta Hort.* 1: 37-41.
- Salazar-García, S., E.M. Lord and C.J. Lovatt.** 1998. Inflorescence and flower development of the 'Hass' avocado (*Persea americana* Mill.) during "on" and "off" crop years. *J. Amer. Soc. Hort Sci.* 123: 537-544.
- Lovatt, C. J.** 1997. Pollination biology and fruit set in avocado. *In Proceedings, Australian Avocado Grower's Federation Inc. and N Z Avocado Growers Association Inc.*, Conference '97: Searching for Quality, Rotorua, New Zealand, September 23-26, 1997. 1: 98-105. [Invited contribution]
- Salazar-Garcia, S. and C. J. Lovatt.** 1997. Use of gibberellic acid to manipulate flowering in the 'Hass' avocado: a preliminary report. *In Proceedings, Australian Avocado Grower's Federation Inc. and N Z Avocado Growers Association Inc.*, Conference '97: Searching for Quality, Rotorua, New Zealand, September 23-26, 1997. 1: 106-111.
- Casale, W. L., V. Minassian, J. A. Menge, C. J. Lovatt, E. Pond, E. Johnson, and F. Guillemet.** 1995. Urban and agricultural wastes for use as mulches on avocado and citrus for delivery of microbial biocontrol agents. *J. Hort. Sci.* 70: 315-332.
- Lovatt, C. J.** 1994. Does an avocado early bloom spray make dollars and sense? *Calif. Grower* 18: 13-15.
- Blanke, M. M. and C. J. Lovatt.** 1992. Anatomy and transpiration of the avocado inflorescence. *Ann. Bot.* 71: 543-547.
- Lovatt, C. J.** 1991. Factors affecting fruit set/early fruit drop in avocado. 1990 *Calif. Avocado Soc. Yearbook* 74: 193-199. [Invited contribution]
- Lovatt, C. J. and A. H. Cheng.** 1990. Comparison of some aspects of nitrogen metabolism of avocado with citrus. *Acta Hort.* 2: 489-495. [Invited contribution]
- Nevin, J. M., C. J. Lovatt, and T. W. Embleton.** 1990. Problems with urea-N foliar fertilization of avocado. *Acta Hort.* 2: 535-541. [Invited contribution, through T. W. Embleton]
- Nevin, J. M., C. J. Lovatt, I. L. Eaks, and H. D. Ohr.** 1990. Separation of the effects of drought and infection by *Phytophthora cinnamoni* on 'Hass' avocado. *Acta Hort.* 2: 729-736. [Invited contribution, through H. D. Ohr]
- Nevin, J. M. and C. J. Lovatt.** 1989. Changes in starch and ammonia metabolism during low temperature stress-induced flowering in 'Hass' avocado. A preliminary report. *S. Afr. Avocado Growers' Assoc. Yrbk.* 12: 21-25. [Invited contribution]

ATTACHMENT 2

Garner, L.C. 2004. Characterization and manipulation of flower and fruit abscission of 'Hass' avocado (*Persea americana* Mill.). Univ. Calif., Riverside, PhD Diss. UMI No. 3130259.

Salazar-García, S., E.M. Lord and C.J. Lovatt. 1998. Inflorescence and flower development of the 'Hass' avocado (*Persea americana* Mill.) during "on" and "off" crop years. J. Amer. Soc. Hort Sci. 123: 537-544.

Table 1. Effect of PGR treatments initiated in Spring 2002 on 3-year cumulative total kg fruit and kg fruit of packing carton sizes 84, 70, 60, 48, 40, and greater than 40 per tree of ‘Hass’ avocado trees harvested in 2003, 2004 and 2005.

PGR treatment	Total	Packing carton size							
		84	70	84+70	60	48	40	60+48+40	>40
----- <i>kg fruit/tree</i> -----									
GA ₃	63.41	1.70	8.22 a ^z	9.92	14.21	21.62	13.38 c	49.21	17.67 c
Prohexadione-Ca	79.82	1.13	6.33 ab	7.46	13.75	31.49	19.83 abc	65.07	27.11 abc
6-Benzyladenine	78.88	0.87	4.66 b	5.53	10.06	28.69	25.10 ab	63.85	34.61 a
CPPU	69.25	2.00	6.32 ab	8.31	11.82	27.18	15.97 bc	54.96	21.94 bc
GA ₃ and Prohexadione-Ca	77.30	1.16	4.66 b	5.81	10.60	28.34	25.34 a	64.28	32.55 ab
Control	76.89	2.06	8.76 a	10.82	16.39	31.34	14.52 c	62.25	18.34 c
<i>P</i> -value	0.8148	0.2330	0.0942	0.1185	0.2000	0.7348	0.0300	0.7340	0.0282

^z Values in a vertical column followed by different letters are significantly different at specified *P* levels by LSD Test.

Table 2. Effect of PGR treatments initiated in Spring 2002 on total kg fruit and kg fruit of packing carton sizes 84, 70, 60, 48, 40, and greater than 40 per tree *averaged across 3 years of the study* of ‘Hass’ avocado trees harvested in 2003, 2004 and 2005.

PGR treatment	Total	Packing carton size							
		84	70	84+70	60	48	40	60+48+40	>40
----- <i>kg fruit/tree</i> -----									
GA ₃	21.14	0.68	3.33 a ^z	4.00	5.89	7.06	3.31 c	16.25	4.18 c
Prohexadione-Ca	26.61	0.38	2.20 ab	2.59	4.66	10.37	6.59 ab	21.62	8.99 ab
6-Benzyladenine	26.29	0.31	1.72 b	2.03	3.64	9.81	8.13 a	21.57	10.82 a
CPPU	23.08	0.75	2.50 ab	3.26	4.45	9.01	4.73 bc	18.19	6.37 bc
GA ₃ and Prohexadione-Ca	25.77	0.40	1.67 b	2.06	3.65	9.55	8.15 a	21.36	10.50 a
Control	25.63	0.73	3.22 a	3.95	5.72	10.53	4.38 bc	20.63	5.42 bc
<i>P</i> -value									
Treatment (T)	0.8148	0.2390	0.0808	0.1006	0.1814	0.7197	0.0033	0.7072	0.0029
Date (D)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
T x D	<0.0001	0.0148	0.0018	0.0022	<0.0001	0.0047	0.0274	0.0008	0.0139

^z Values in a vertical column followed by different letters are significantly different at specified *P* levels by LSD Test.

Table 3. Effect of GA₃ (25 mg/L) applied at the end of June–beginning of July and March on ‘Hass’ avocado yield.

GA ₃ treatment	2-year average		2-year cumulative	
	Total yield	60+48+40	Total yield	60+48+40
----- <i>kg fruit/tree</i> -----				
June–July	58.96 a ^z	50.79 a	117.92 a	100.08 a
March	48.60 b	39.81 b	97.19 b	80.37 b
Control	45.39 b	38.76 b	90.79 b	77.44 b
<i>P</i> -value				
Treatment (T)	0.0239	0.0177	0.0239	0.0337
Tree status (S)	<0.0001	<0.0001	–	–
T x S	0.4586	0.2377	–	–

^z Values in a vertical column followed by different letters are significantly different at specified *P* levels by Duncan’s Multiple Range Test.