

CALIFORNIA AVOCADO COMMISSION

PROJECT PLAN - RESEARCH GRANT PROPOSAL

Proposal Budget Requested: \$42,320

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

Anticipated Duration of Project: 4 years

This project is: On-going, year 4 of 4

Project Title: PGR strategies to increase yield 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):

Postdoctoral Research Plant Physiologist (TBA); Elias Serna, Lab. Asst.

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

Per instructions, Carol Lovatt's and Elias Serna'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.

Average yields of the 'Hass' avocado in California have been low (5,700 lbs./a; 6.9 metric tons/ha) (Arpaia, 1998) over the past decade. In Australia and New Zealand 'Hass' production is reported to be 15 and 9.4 metric tons/ha, respectively (Lovatt, 1999). One major difference between 'Hass' trees grown in Australia and New Zealand versus California is that 'Hass' trees in California have a significantly higher proportion of proleptic to sylleptic shoots, whereas 'Hass' trees in Australia and New Zealand have significantly more sylleptic shoots. Proleptic shoots arise from dormant buds, whereas sylleptic shoots do not arise from dormant buds but simultaneously with the development of the main axis as lateral shoots (Thorp and Sedgley, 1992). If one follows the development of shoots from an original proleptic or sylleptic shoot, the probability is high that proleptic and sylleptic shoots will produce proleptic shoots and the probability that either shoot type will produce sylleptic shoots is low (Salvo, 2005). The net result is that 20-year-old 'Hass' avocado trees in California have three times as many proleptic as sylleptic shoots. Sylleptic shoots are more productive than proleptic shoots. For two successive years, sylleptic shoots produced significantly more inflorescences ($P \leq 0.01$) and set significantly more fruit ($P \leq 0.04$). In addition, at our N study in Somis, N fertilizer treatment had no statistically significant effect on sylleptic versus proleptic shoot number over the 3 years during which these measurements were made. However, shoot type significantly affected vegetative shoot production, inflorescence number and yield per shoot with sylleptic shoots producing 2-fold more vegetative shoots ($P \leq 0.001$), 3-fold more inflorescences ($P \leq 0.001$) and 2-fold more fruit ($P \leq 0.05$) than proleptic shoots.

Use of 6-benzoyladenine (BA) and gibberellic acid (GA_{4+7}) was shown by Thorp and Sedgley (1993a,b) to increase sylleptic shoot production of young 'Hass' avocado trees in Australia. The success of this treatment was confirmed on 3-year-old 'Hass' avocado trees in California (Salvo, 2005). Foliar application of a spray containing BA (0.05%) and GA_{4+7} (0.05%) in the summer (July) significantly increased the number of sylleptic shoots ($P \leq 0.02$) and significantly reduced the number of proleptic shoots ($P \leq 0.0004$) compared to the untreated control. BA (0.05%) and GA_{4+7} (0.05%) or BA (0.05%) with 10-fold less GA_{4+7} (0.005%) applied in the winter (January) were equally effective in increasing sylleptic shoot number ($P \leq 0.001$) and reducing proleptic shoot number ($P \leq 0.0008$) compared to the untreated control, but the winter PGR applications increased sylleptic shoot number more than 3-fold compared to the summer application.

Given the significantly greater productivity of sylleptic shoots and the low percentage of sylleptic shoots on 'Hass' avocado trees in California, PGR treatments that can increase sylleptic shoot production would seem worthy of further study in a commercially bearing 'Hass' orchard.

Another factor contributing to low yields is the low percent fruit set ($< 0.1\%$) of the 'Hass' avocado, even in healthy, well-managed orchards (Whiley and Schaffer, 1994). Although 'Hass' flowers profusely, the abscission of thousands of flowers and small fruit occurs each year (Inoue and Takahashi, 1990; Lahav and Zamet, 1975; Slabbert, 1981). Through her dissertation research Garner (2004) determined that 100% of flowers that abscised were not fertilized and had degenerate ovules despite the fact that 100% were pollinated. She also document that 65% to 75% of the young developing fruit that abscised were unfertilized, whereas another 20% of developing fruit that abscised were fertilized but had degenerate seed coats and ceased growing prior to abscission. These fruit accumulated IAA, ABA and IPA. Whether the accumulation of PGRs was the cause or a consequence of growth inhibition is unknown at present. Fertilized fruit that abscised have the potential to successfully develop into a mature fruit. Peak abscission of these fruit was June 8th of the off-crop year and June 29th of the on-crop year (almost exactly 4 weeks after peak flower abscission each year). Application of PGRs known for their ability to reduce abscission at the times that Garner (2004) has identified as critical should improve the efficacy of the PGR treatment to increase yield.

In our previous PGR study, CPPU applied at the end of June drop in July was intermediate between GA₃ applied at the cauliflower stage and the untreated control in increasing the pack out of large size fruit. Based on the results of Garner (2004), it was likely that the July application was too late to increase yield (peak abscission is in June) and too early to increase fruit size. Avocado fruit exhibited a significant increase in growth rate (exponential growth phase) by August 23 to 31, not in July as previously believed. Better timing of PGRs known to increase size should improve their efficacy.

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 industry objectives, expectations and vision 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. Salvo (2005) and Garner (2004) dissertation research provide additional basic information to guide our choice of PGR and timing of their application to improve their efficacy. We now have data to successfully demonstrate the efficacy of GA₃ and that the cauliflower stage is the best phenological stage for GA₃ application. The next step is to demonstrate that yield or fruit size responds incrementally to increases in GA₃ dose (per Joseph Vandepuete, Department of Pesticide Regulation).

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.)

Specific goals of the proposed research are to increase the productivity of 'Hass' avocado orchards by increasing yield of commercially valuable large size fruit to increase grower income. The project objectives are: (1) to increase yield by annually increasing the number of sylleptic shoots; (2) to increase yield by increasing fruit retention during June drop; (3) to increase fruit size; and (4) to collect dose response data as the next step toward adding avocado to the label for GA₃.

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.

To meet objective 1, Typy (6-BA, 1.8% + GA₄₊₇, 1.8%) will be applied at 0.05% (500 pm) and at 0.005% (50 ppm): *i*) at the initiation of the summer vegetative shoot flush, and *ii*) in winter at stage 5 of inflorescence development when perianth formation is initiated on the secondary and tertiary axes. Sylleptic and proleptic shoot growth and return bloom (number of indeterminate and determinate floral shoots) will be determined. To meet objectives 2, AVG will be applied at 250 ppm: *i*) at the cauliflower stage of bloom, *ii*) at full bloom, *iii*) just before June drop starts, and *iv*) at full bloom and again just before June drop starts. To meet objectives 2 and 3, *i*) 2,4-D will be applied at 45 g acid equivalents/acre when fruit are 16-20 mm in diameter and *ii*) 3,5,6-TPA will be applied at 15 ppm when fruit are 24 mm in diameter. To meet objective 4, GA₃ will be applied 10, 25, 60 and 120 ppm at the cauliflower stage of inflorescence development. Untreated trees will serve as the control

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.

Auxins are known to increase fruit set and size. This will be the first test of their utility to the avocado industry. Both 2,4-D and 3,5,6-TPA are best used when applied at a concentration related to fruit size. The sizes and doses were borrowed from citrus but selected from a range of possibilities using the basic information about fruit size and June drop provided by Garner (2004). The preliminary research of Garner (2004) was the basis for the treatments with AVG. Her work, to our knowledge, was the first to test the use of AVG on avocado. The earlier research of Thorp and Sedgley (1993) established that BA+GA₄₊₇ increased sylleptic shoot

number. Salvo (2005) confirmed that the effect occurred under California conditions. The research proposed herein will advance our understanding of PGRs, tree physiology and architecture, and fruit development. In addition, it will provide a set of data needed for adding avocado to the label for GA₃.

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

Research to meet objectives 1, 2 and 3 was initiated in year 1 and repeated each year thereafter. For objective 1, summer applications of Typy (250 mg/L) and GA₃ (100 mg/L) significantly increased in the total number of sylleptic shoots ($P = 0.0022$) compared to all other treatments and the untreated control. Both treatments increased the total number of nodes (sites that bear inflorescences) on sylleptic shoots produced by the spring, summer and fall shoot flushes compared to all other treatments including the control ($P = 0.0013$). Thus, Typy (250 mg/L) and GA₃ (100 mg/L) significantly increased the complexity of the tree compared to the control. While promising, the effect of these treatments on yield following a heavy on-crop year will not be known until harvest in 2007. The effect of the treatments following a light off-crop year will be determined with 2008 harvest.

For objectives 2 and 3, AVG, 2,4-D and 3,5,6-TPA continue to show promise in increasing the yield of commercially valuable large size fruit. When averaged across the 2-years of the study, AVG (applied at full bloom) and 2,4-D (applied when fruit are 24 mm in diameter) significantly increased the 2-year average yield of fruit greater than size 60 as kilograms per tree ($P = 0.0168$) and AVG (full bloom), 2,4-D and 3,5,6-TPA (applied when fruit are 24 mm in diameter) significantly increased the yield of fruit of packing carton size 48 as both kilograms and number per tree ($P = 0.0050$). As 2-year cumulative yield, 2,4-D significantly increased the yield of fruit of packing carton sizes 60+48+40 and > 60 as both kilograms and number per tree compared to the control ($P = 0.0625$). All treatments numerically, but not significantly, reduced the 2-year average and cumulative yields of small size fruit (packing carton sizes 84+70) as kilogram and number per tree. Averaged across the 2 years of the experiment, no PGR had any effect on any fruit quality parameter evaluated. Averaged across the 2 years of the study, AVG and 2,4-D increased net yield of fruit of packing carton sizes 60+48+40 above that of the control by 2262.6 and 3989.2 lbs/110 trees per acre per year, respectively. Although not the objective of these two treatments, total yield was increased by a net of 897.3 and 3045.9 lbs/110 trees per acre per year with AVG and 2,4-D, respectively. The cost of the 2,4-D (CitrusFix[®] AMVAC Corp.) to achieve the net increase in total yield and yield of large size fruit was \$14.95/acre. The cost for AVG (ReTain[®] Valent BioSciences) would be between \$757.36 to \$946.70/acre.

Due to the heavy rains in year 1, we could not apply the GA₃ treatments at the proper time for objective 4, so with permission from G. Witney, we delayed this objective for one year. All GA₃ treatments were applied at the optimal time during year 2 of this objective of the project.

For objective 4, the results obtained with the harvest of 2007, which occurred earlier than usual and immediately after the freeze, were consistent with previous results at other sites, the off-crop yield was not affected positively or negatively by any GA₃ concentration tested. A positive effect of GA₃ concentration on 2008's yield, the putative on-crop, is anticipated and will be critical.

Indicate expected duration of project:

We are requesting funding for 3 crop years (4 funding years). Due to alternate bearing, a 4 year of yield

2007-08 PROJECT BUDGET

Salaries & Benefits:

Project Leader: Carol Lovatt	<u>0</u>
Postdoctoral Researcher II 1 TBA (@ \$2,806/mo., 50% x 11 mo. plus \$2,890/mo., 100% x 1 mo.	<u>18,323</u>
Laboratory Assistant: Elias Serna (\$12.57/h x 40 h/mo. x 11 mos. plus 1 mo. @, \$12.95/h x 40h/mo. to provide help with treatment applications, data collection, harvest)	<u>6,049</u>
SRAs:	<u>0</u>
Benefits: TBA 32%	<u>5,863</u>
ES 44%	<u>2,662</u>
Subtotal:	<u>32,897</u>
Supplies/Expenses: Nutrient analysis of 150 samples @ \$35 per sample, field supplies for application and harvest	<u>5,250</u>
Equipment:	<u>0</u>
Operating Expenses:	<u>0</u>
Travel: 12 roundtrips to Irvine @ 76 x \$0.41/mi. = \$374 12 roundtrips to Santa Paula @ 268 x \$0.41/mi. = \$1,319 36-car days x \$25/day = \$900 20-man days per diem x \$79/day = \$1,580	<u>4,173</u>
Other:	<u>0</u>
Total:	<u>42,320</u>

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)

Valent BioSciences paid for the crop destruct for the AVG treatments for the past 2 years at a cost of over \$16,000 thus far. I had to cover the crop destruct from the 2,4-D and 3,5,6-TPA from my OR funds. If the yield results consistently show a positive effect of 2,4-D or 3,5,6-TPA on fruit size, I hope to be able to convince the companies involved to cover the cost of destroying the crop treated with their product.

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, 2007	\$8,464
April 30, 2007	\$8,464
July 31, 2007	\$8,464
October 31, 2007	\$8,464

The remaining 20% (\$8,464) due upon receipt of the final report for year 4 on October 31, 2007.

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

After the harvest is completed in June 2007 and the data analyzed and shared with Valent BioSciences, I need to get a commitment from them to cover the cost of destroying fruit treated with AVG for the third harvest in year 4.

Projected budget for FY 04-05 \$39,545 05-06 \$40,355 06-07 \$42,000 07-08 \$ 42,000

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 and 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.
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- Lovatt, C.J. and G. Witney.** 2001. Nitrogen Fertilization of the 'Hass' avocado in California. *AvoResearch* 1(3):1-4,11.
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- Salazar-Garcia, 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.
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- Salazar-Garcia, 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.
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- 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.

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- 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.
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- 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]
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ATTACHMENT 2

- Arpaia, M.L.** 1998. California Avocado Grower. Vol. 2 (April), p. 1.
- 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.
- Inoue, H. and B. Takahashi.** 1990. Studies on the bearing behavior and yield composition of the avocado tree (in Japanese). J. Japan. Soc. Hort. Sci. 59: 487-501.
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