PGR Strategies to Increase Yield of 'Hass' Avocado

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The goal of this research is to increase net income per acre for growers of the 'Hass' avocado in California. To meet this goal we are developing plant growth regulator (PGR) strategies to increase total yield and yield of commercially valuable large size fruit and simultaneously collecting the efficacy data necessary to satisfy the requirements of the California Department of Pesticide Regulation (DPR) to have the successful plant growth regulators added to an existing label so that they can be legally used in avocado production in California. Note that PGRs are considered pesticides. The specific objectives of this research are: (1) to increase yield by annually increasing the number of sylleptic shoots in the canopy; (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 GA_3. To meet these objectives, three separate field projects are being conducted.

Executive Summary.

- PGR strategies initiated in 2005 and applied annually increased the number of sylleptic shoots produced in spring 2006 and 2007. The ratio of syllepsis to prolepsis in the canopy of control trees was 9% in spring 2006 but 25% in the canopy of PGR-treated trees in 2006, increasing to 66% for PGR-treated trees by spring 2007. Since PGR-treated trees had 2-fold more sylleptic shoots than control trees in spring 2007, it is anticipate for the 2007-2008 harvest that PGR-treated trees will have increased yield and reduced alternate bearing relative to control trees.
- Averaged across the 3 years of the experiment (two off-crops and 1 on-crop), AVG and 2,4-D increased the net yield of commercially valuable large size fruit (packing carton sizes 60 + 48 + 40) by 1,761 and 1,804 lbs/110 trees/acre/year more than the control, respectively. These two treatments also increased the net yield of fruit greater than packing carton size 60 by 1,940 and 1,649 lbs/110 trees/acre/year more than the control, respectively. The 3-year average net increase in total yield was approximately 1000 lbs/acre/year. The cost of 2,4-D (CitrusFix® AMVAC Corp.) to achieve the net increase in total yield and yield of large size fruit was $15/acre. The cost for AVG (ReTain® Valent BioSciences) would be between $757 to $947/acre. The treatments were more effective in the on-crop year than the two off-crop years. Thus, the harvest of 2007-2008, a putative on-crop, will be important for confirming efficacy.

- In previous research the potential of GA_3 to increase grower income was demonstrated. GA_3 (25 mg/L) applied at the cauliflower stage of inflorescence development resulted in a net increase in 2-year cumulative total yield of 6,063 lbs fruit/acre (based on 110 trees/acre) and 2-year cumulative yield of commercially valuable large size fruit (packing carton sizes 60 + 48 + 40) of 4,098 lbs/acre more than untreated control trees. The cost of GA_3 (ProGibb® Valent BioSciences) to achieve the net increase in total yield and yield of large size fruit was $16/acre. We are now at the next step required by the DPR for making GA_3 available for use in avocado production - demonstration of a GA_3 dose effect on avocado yield. GA_3 is also more effective in on-crop than off-crop years. Results obtained for 2007-2008, a putative on-crop year, will be critical to this project.

Project 1. Objective. To use PGRs to increase the number of sylleptic shoots, which are more productive than proleptic shoots.

Background Information and Justification. Avocado trees produce two types of shoots: proleptic shoots (Fig. 1, left side) and sylleptic shoots (Fig. 1, right side).

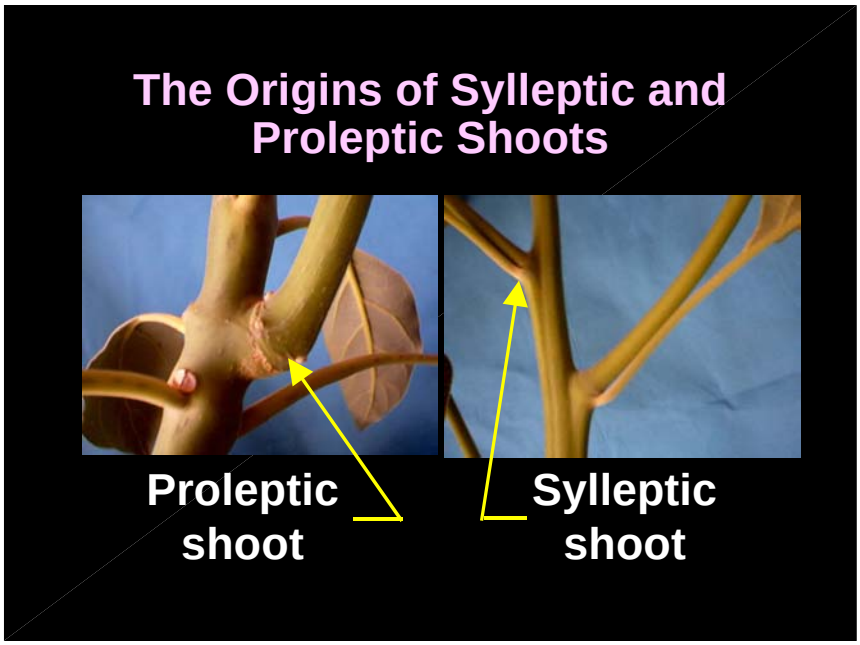

Figure 1.

Proleptic shoots develop from lateral buds near the apical (terminal) bud that have gone through a dormant period. Proleptic shoot buds produce bud scale scars when the shoots begin growth in spring. In contrast, sylleptic shoots develop from lateral meristems that develop *de novo* on a primary shoot as it develops from spring through fall (Fig. 1, right). Proleptic shoots have limited branching, whereas sylleptic shoots increase canopy complexity. This greater complexity means more sites on which to bear inflorescences and fruit. Previous research demonstrated that foliar-applied 6-benzyladenine plus gibberellic $acid_{4+7}$ increased sylleptic shoot number (64% and 300% in two separate experiments), decreased proleptic shoot number (38% and 46%, respectively), and increased the proportion of sylleptic shoots from 16.67% to 50% of the canopy. We are now attempting to achieve this same effect on syllepsis in a commercial 'Hass' orchard and attain a concomitant yield increase.

Approach. In a mature, commercially producing 'Hass' avocado orchard in Irvine owned by the Irvine Company, we are testing the ability of Typy® (6-BA; 1.8% + GA_{4+7}; 1.8%) at 0.025% (250 mg/L) and 0.005% (50 mg/L) and ProGibb® (GA_3) at 0.01% (100 mg/L) applied *i*) at the initiation of the summer vegetative shoot flush (June-July) and *ii*) at bud break (February) to increase sylleptic shoot growth, floral intensity the following spring, and yield. The PGR treatments were first applied in 2005. Stage 5 of inflorescence development (January) proved to be too early. The application time was changed to bud break (February) in 2006.

Results. The results are summarized in a time line (Fig. 2a, b). By looking at the ratio of proleptic to sylleptic shoots that developed during spring 2006 and 2007, it can be seen that the PGR treatments are increasing the number of sylleptic shoots that develop in spring and gradually increasing the ratio of syllepsis to prolepsis relative to the control. In spring 2006, there were 10-fold more proleptic than sylleptic shoots for the control, but on average only 3-fold more proleptic to sylleptic shoots for the PGR-treated trees. Typy (250 mg/L) applied in July also reduced the number of proleptic shoots that developed each spring in addition to increasing sylleptic shoot number, which further increased the ratio of syllepsis to prolepsis. January application of this treatment reduced the 2006-2007 yield compared to the control (Fig. 2a) and was replaced with a February bud break application.

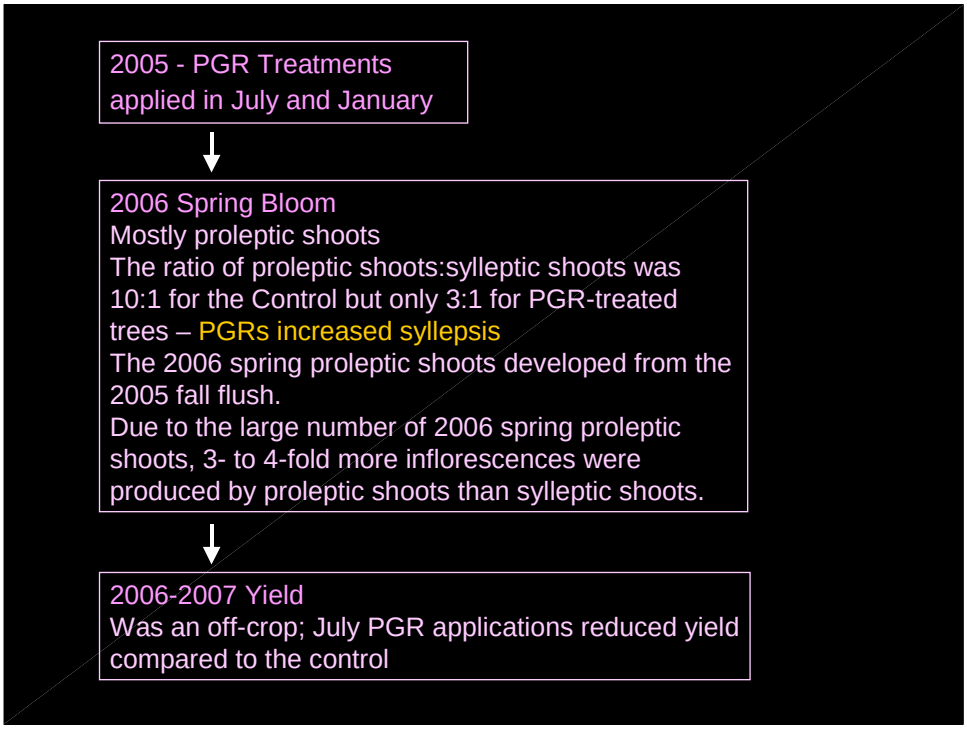

Figure 2a.

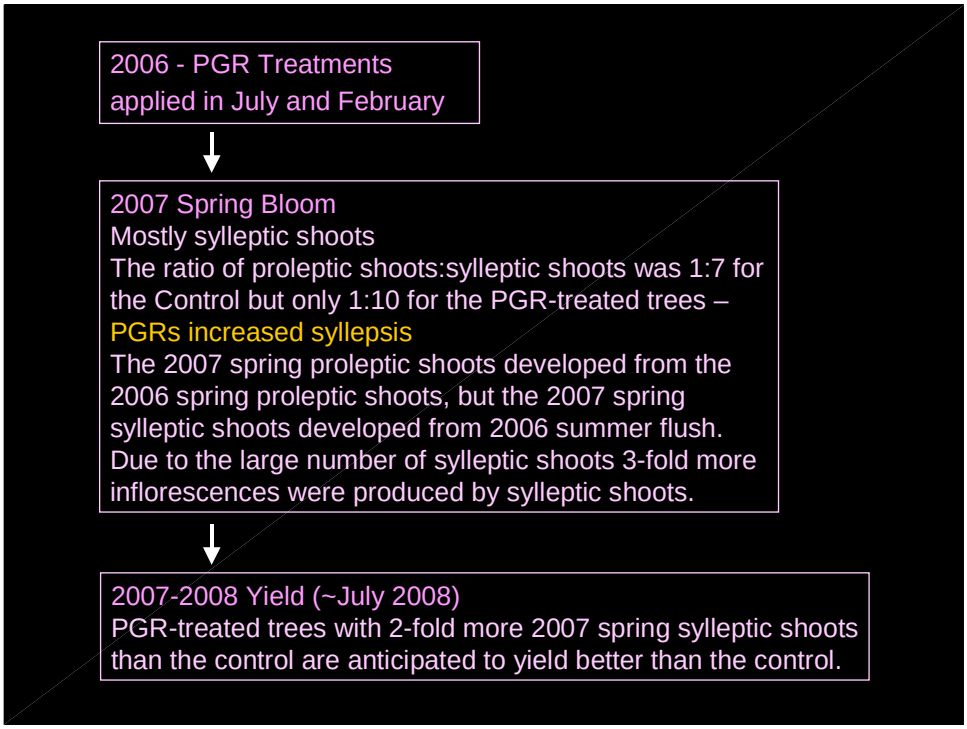

Figure 2b.

Typy (250 mg/L) applied in July increased sylleptic shoot number to a value more than 2-fold greater than the control in spring 2006. In spring 2007, there were more sylleptic than proleptic shoots (Fig. 2b). For the control, one out of every seven shoots was proleptic, but for PGR-treated trees only 1 in every 10 shoots was proleptic. Typy (250 mg/L) applied in July 2006 and GA_3 (100 mg/L) applied in February 2006 resulted in approximately 2-fold more sylleptic shoots than the control. If sylleptic shoots are indeed more productive (Thorp and Sedgley, 1993), we should see a positive effect on yield when the 2007-2008 crop is harvested (~July).

This research is also enabling us to quantify the specific role of proleptic versus sylleptic shoot development in alternate bearing of the 'Hass' avocado. The heavy on-crop year was characterized by a vastly greater number of proleptic shoots than sylleptic shoots (10:1 for control trees). Treatments that increase sylleptic shoot number and/or reduce proleptic shoot number should reduce the severity of alternate bearing. Harvest of the 2007-2008 crop along with the data we will collect during the 2008 spring bloom compared with data collected during spring 2006 and 2007 and the 2005-2006 and 2006-2007 harvests will confirm or refute this hypothesis.

Take Home Message. Typy® (6-BA; 1.8% + GA_{4+7}; 1.8%) at 0.025% (250 mg/L) and 0.005% (50 mg/L) and ProGibb® (GA_3) at 0.01% (100 mg/L) applied at the initiation of the summer vegetative shoot flush (June-July) and *ii*) at bud break (February) are increasing the number of sylleptic shoots produced in spring, with the benefit of gradually shifting the ratio of syllepsis to prolepsis in favor of syllepsis. PGR-treated trees had 2-fold more sylleptic shoots than control trees in spring 2007. Thus, we anticipate an increase in yield relative to the control with an accompanying reduction in the severity of alternate bearing.

Project 2. Objective. To use the PGRs AVG to increase fruit retention during June drop and 2,4-D and 3,5,6-TPA to increase fruit size.

Background Information and Justification. AVG (aminoethoxyvinylglycine, ReTain®) is an inhibitor of ethylene biosynthesis and, thus, inhibits the process of abscission and increases flower and fruit retention during the periods of early and June drop to increase yield. The PGRs 2,4-D (2,4-dichlorophenoxyacetic acid, CitrusFix®) and 3,5,6-TPA (3,5,6-trichloropehoxypropionic acid, Maxim®) are well-known synthetic auxins used to improve fruit set and fruit size by increasing the amount of xylem in the fruit peduncle and, hence, the transport of water, nutrients, metabolites and hormones into the fruit.

Approach. In a second mature, commercially producing 'Hass' avocado orchard in Irvine owned by the Irvine Company, we are testing the efficacy of AVG (250 mg/L) applied *i*) at the cauliflower stage of inflorescence development, *ii*) at full bloom, *iii*) just before June drop starts, and *iv*) at full bloom and again just before June drop to increase yield by increasing fruit retention during June drop. We are also testing the efficacy of *i*) 2,4-D (45 g acid equivalents/acre) applied when fruit are 16-20 mm in diameter and *ii*) 3,5,6-TPA (15 mg/L) applied when fruit are 24 mm in diameter to increase yield by increasing fruit retention during June drop and by increasing fruit size. We thank the manufactures of the PGRs, who are paying for fruit that must be destroyed in this project.

Results. The crop harvested in July 2007 was an off-crop. Trees treated with AVG at full bloom produced the highest yield, but it averaged only 35 lbs per tree. Trees receiving this treatment also had the highest yield of fruit of packing carton sizes 60 + 48 + 40 and fruit greater than packing carton size 60. Due to the low yield, treatment effects were not significantly different from the control in 2007.

Averaged across the 3 years of the experiment (two off-crops and one on-crop), AVG (250 mg/L) applied at full bloom and 2,4-D (45 g acid equivalents/acre) applied when fruit are 16-20 mm in diameter continued to have a significant effect on yield and fruit size (Fig. 3a, b). Averaged across the 3 years of the experiment, no PGR had an effect on any fruit quality parameter evaluated. The greatest effect on yield and fruit size was achieved in the on-crop year. Averaging in the yield obtained for 2007 greatly reduced the average effect of these treatments on yield (Fig. 3a, b) compared to the 2-year average for one off- and one on-crop year: AVG and 2,4-D produced a 2-year average net increase in yield of fruit of packing carton sizes 60 + 48 + 40 of 2,263 and 3,989 lbs/110 trees/acre/year, respectively, more than the control. Thus, the harvest of 2007-2008, a putative on-crop, will be important for confirming the efficacy of these two PGRs.

Effect of PGRs on yield and fruit size of 'Hass' avocado averaged across the 3 years of the study.

Treatment	Total Yield	Yield of 60+48+40	> 60
	---------- *kg/tree* ----------		
AVG			
Full bloom	38.69	30.56 a	33.10 a
Exp. fruit growth	37.31	26.80 ab	28.73 ab
Full bloom + exp. fruit growth	33.89	24.92 ab	26.81 b
2,4-D	39.07	30.74 a	31.93 a
3,5,6-TPA	35.23	27.60 ab	29.91 ab
Control	34.65	23.30 b	25.14 b
P-value			
Treatment	0.0597	0.0155	0.0257
Year	<0.0001	<0.0001	<0.0001
T x Y	0.1039	0.0130	0.0188

[z]Means followed by different letters within a vertical column are significantly different by Fisher's Protected LSD test, *P* = 0.05.

Figure 3a.

Yield Benefits

AVG @ full bloom	Net increase in 3-yr average yield of fruit size > 60 = 1,940 lbs/acre/year
2,4-D @ 16-20 mm fruit diameter	Net increase in 3-yr average yield of fruit size > 60 = 1,649 lbs/acre/year

Based on 110 trees/acre.

Figure 3b.

Take Home Message. Averaged across the 3 years of the experiment, AVG and 2,4-D increased the net yield of commercially valuable large size fruit (packing carton sizes 60 + 48 + 40) by 1,761 and 1,804 lbs/110 trees/acre/year more than the control, respectively. These two treatments also increased the net yield of fruit greater than packing carton size 60 by 1,940 and 1,649 lbs/acre/year, respectively, more than the control. The 3-year average net increase in total yield was 970 and 1,072 lbs/acre/year, respectively.

Project 3. Objective. To demonstrate that increasing the dose of GA_3 incrementally increases total yield and/or yield of commercially valuable large size fruit (packing carton sizes 60 + 48 + 40).

Background Information and Justification. Previous research demonstrated that the application of GA_3 (25 mg/L) at the cauliflower stage of inflorescence development resulted in a net increase in total yield of 6,063 lbs fruit per acre (based on 110 trees per acre) above that of the untreated control. The increase in yield resulted in a net increase in yield of commercially valuable large size fruit (packing carton sizes 60 + 48 + 40) of 4,098 lbs per acre more than the untreated control trees. Application of GA_3 at this time had the additional benefits of increased size of the mature fruit on the tree and reduced blackening of the peel at late harvest. The next step towards making GA_3 available to growers for use in avocado production is to demonstrate a GA_3 dose effect on avocado yield as required by CA DPR.

Approach. In a commercially producing 'Hass' avocado orchard in Santa Paula owned by the Limoneira Company, we are testing the efficacy of GA_3 (ProGibb® Valent BioSciences) at 0 (control), 10, 25, 62.5 and 156 mg/L applied at the cauliflower stage of inflorescence development to increase avocado yield and fruit size and delay peel blackening. Total yield and/or yield of commercially valuable large size fruit and/or the proportion of green- vs. black-peeled fruit should increase incrementally with increasing GA_3 concentrations from 0 to 10 to 25 to 62.5 mg/L, with the difference in yield responses to 25 vs. 62.5 mg/L GA_3 not significantly different. The high concentration of 156 mg/L GA_3 is included to establish a phytotoxicity threshold as requested by CA DPR.

Results. Consistent with previous results at other sites, the off-crop yield was not affected positively or negatively by any GA_3 concentration tested.

Take Home Message. A positive effect of GA_3 concentration on next year's yield, the putative on-crop, is anticipated and will be critical to the success of this project.

Literature Cited

Thorp, T.G. and M. Sedgley. 1993. Manipulation of shoot growth patterns in relation to early fruit set in ‘Hass’ avocado (*Persea americana* Mill.). Scientia Hort. 56:147–156.