

ProGibb LV Plus® Plant Growth Regulator to Increase Fruit Size and Yield of Avocados

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On March 27, 2018, gibberellic acid (GA_3) was approved for use on avocado to increase fruit size and yield. The only material registered for this purpose is ProGibb LV Plus®, a low volatile organic compound (LVOC) formulation, manufactured by Valent BioSciences, Corporation. The older formulation sold under the name ProGibb® and other generic GA_3 products cannot be used. Note: (i) the restricted entry interval is only 4 hours; (ii) the preharvest interval is 0 days; and (iii) ProGibb LV Plus® is OMRI (Organic Materials Review Institute) listed and can be used in certified organic orchards.

ProGibb LV Plus® Usage Instructions

Application Timing. ProGibb LV Plus® is applied as a foliar spray at the cauliflower stage of avocado inflorescence development (Figure 1). The applications should be made when 50 percent of the trees in the block have 50 percent of their bloom at the cauliflower stage. This means that 25 percent of the bloom will be at an earlier stage of inflorescence development and 25 percent will be approaching bloom (open flowers). If you are unable to make the application at this time, being slightly late in applying the treatment affords better efficacy than being too early. Applications made at full bloom are typically not effective.

Dose and Dilution Rate. The sprays should be applied like a pesticide spray to give full canopy coverage, especially of the developing inflorescences, but not sprayed to run-off. For ground application, use 12.5 fluid ounces of ProGibb LV Plus® (equivalent to 25 grams of active ingredient) in 100 gallons of water per acre. For aerial (helicopter) application, use 12.5 fluid ounces in 75 gallons of water per acre. The maximum allowable dose is 12.5 fluid ounces per acre per year. The results



Figure 1. Cauliflower stage inflorescence during early bloom of 'Hass' avocado.

of our research documented that lower and higher doses are less effective.

Spray Solution pH. The final pH of the spray solution in our research was between pH 5.5 to 6.0. ProGibb LV Plus® is stable at pH 4.0 to 8.5. The pH of the water used should be adjusted accordingly. Prolonged exposure of GA_3 to a pH > 8.5 should be avoided.

Spray Volume. For ground applications, we used an equivalent amount of GA₃ with a spray volume of 200 to 250 gallons of water per acre depending on tree size. Best practice is to achieve good coverage without causing the material to run-off the tree and with minimum spray volume left in the tank after application.

Use of spray volumes greater than 100 gallons of water per acre for ground application is at the discretion of the Agricultural Commissioner for each county. Consult with your County Agricultural Commissioner, if you wish to apply ProGibb LV Plus® (12.5 fluid ounces per acre) in more than 100 gallons of water per acre as a ground spray.

For aerial (helicopter) application, the greatest efficacy was achieved with ProGibb LV Plus® (12.5 fluid ounces) in 75 gallons of water per acre.

Wetting Agent. In our research, we used the organosilicone surfactants Silwett L-77® or Widespread Max® at a final concentration of 0.05 percent. Similar pure organosilicone type surfactants are acceptable and recommended.

Additional Comments for the Use of ProGibb LV Plus®. The cauliflower stage of avocado inflorescence development represents an important stage in fruit production. Integuments – tissues that will later develop into the seed coat – are forming around the ovule, which after pollination and fertilization will develop into the seed.

Previous research has shown that combining two simple fertilizers, boron (sodium borate) and nitrogen (low-biuret urea)

to ‘Hass’ avocado trees at this stage of inflorescence development results in double pistils, each with an ovule. Thus, at this time, we recommend that other materials **not** be included in the ProGibb LV Plus® spray solution. The California Avocado Commission is testing the efficacy of ProGibb LV Plus® combined with boron and low-biuret urea, respectively, and will share results as they become available.

In general, GA₃ seems to be compatible with low-biuret urea, potassium, zinc and manganese, but the sensitivity of the cauliflower stage of avocado inflorescence development to these spray combinations is unknown. Growers should not apply a combination spray to a large number of trees without first testing the treatment on a few trees over several years to identify any unfavorable interactions, including those precipitated by differences in climate from one year to the next.

In our research, the treatment significantly increased fruit size and yield. Our research also indicated that ProGibb LV Plus® is most effective when there is a good bloom on most of the trees in the orchard and may not be effective when there are only few inflorescences per tree. The target of the ProGibb LV Plus® application is the cauliflower stage inflorescence of the current bloom, but GA₃ applied at this time has been documented to also increase the size and slow the blackening of the peel of mature fruit on the tree. These results are dependent on crop load and how long the fruit remain on the tree before they are harvested.

GA₃ treatment had no negative effects on quality of mature fruit or quality of the fruit that develop from the treated bloom. GA₃ application had no effect on the number of days

Table 1. Effect of GA₃ on two-year average yield and fruit size as pounds and number of fruit per tree in an alternate bearing ‘Hass’ avocado orchard in Irvine.

	Treatment	Total yield	Net increase (%)	Yield of large size fruit ¹	Net increase (%)	Total yield	Net increase (%)	Yield of large size fruit	Net increase (%)
		lb/tree			no. fruit/tree				
2-year avg yield	GA ₃	50.5 a ²	51	37.6 a	47	115 a	60	77 a	51
	Control	33.4 b		25.7 b		72 b		51 b	
Individual year yield averaged across treatments	Year								
	On-year	69.4 a		50.9 a		162 a		105 a	
	Off-year	14.6 b		12.4 b		26 b		22 b	

¹ Large size fruit = packing carton sizes 48+40+36.

² Values within a column followed by different letters are significantly different statistically.

from harvest to “eating ripe” (eating soft), nor on external exocarp (peel) and internal mesocarp (edible portion of the fruit) quality parameters, which included decay, discoloration and vascularization (presence of vascular bundles and associated fibers in the mesocarp). The GA₃ treatment did not alter the ratio between fruit length and fruit width. There was no reduction in mesocarp width and no increase in seed diameter. Germination of the seed within mature fruit was not affected.

Research Trial Data

A note about the data and discussion that follows: All the research trials conducted for the registration of ProGibb LV Plus® were conducted with the old product formulation known as ProGibb®. Valent BioSciences Corporation submitted data to the California Department of Pesticide Regulation during the registration process for the new ProGibb LV Plus® formulation demonstrating product equivalency. All of the data shown are from trials conducted using 25 grams of active ingredient (equivalent to 12.5 fluid ounces of ProGibb LV Plus®) and applied at the cauliflower stage of inflorescence development.

Ground-based Application of GA₃

Alternate Bearing Orchard. Repeated measure analysis was used to determine statistically whether the yield increase resulting from GA₃ application at the cauliflower stage of inflorescence development of ON bloom trees reduced yield the following year. That is to say – did GA₃ application in the ON year make the next year’s OFF crop more OFF?

Despite large differences in yield between the two crop years in this experiment (69.4 vs. 14.6 pounds per tree, see Table 1), GA₃ applied as directed significantly increased yield and fruit size when averaged across both years of the experiment. Compared to untreated control trees, GA₃ significantly increased the two-year average total yield of pounds per tree by 51 percent and the number of fruit per tree by 60 percent.

GA₃ increased the two-year average yield of commercially valuable large size fruit (packing carton sizes 60+48+40) of pounds per tree by 47 percent and the number of fruit per tree by 51 percent, compared to untreated control trees (Table 1). The results provide evidence that the response to GA₃ was positive in both years of the experiment and demonstrate that GA₃ application during an ON bloom did not exacerbate alternate bearing.

Untreated control trees were used for comparison in the results listed below.

Table 2. Effect of GA₃ on yield and fruit size of ‘Hass’ avocado trees in Corona.

Treatment	Total yield	Net increase (%)	Yield of large size fruit ¹	Net increase (%)
GA ₃	74.7 a ²	84	34.3 a	128
Control	40.6 b		15.0 b	

¹ Large size fruit = packing carton sizes 48+40+36.

² Values within a column followed by different letters are significantly different statistically.

Fruit Size and Yield: Corona. In Corona, CA, GA₃ was applied to ten-year-old ‘Hass’ avocado trees on Duke 7 clonal rootstock.

Results:

- Increased the total pounds of fruit per tree 84 percent (Table 2)
- Increased the yield of large size fruit (packing carton sizes 48+40+36) by 128 percent (Table 2)
- Net increase in total yield of 3,751 pounds of fruit per acre (110 trees per acre)
- Net increase in large size fruit of 2,123 pounds per acre

Table 3. Effect of GA₃ on yield and fruit size as pounds and number of fruit per tree in an alternate bearing ‘Hass’ avocado orchard in Irvine.

Treatment	Year 1 yield			
	Total yield	Net increase (%)	Yield of large size fruit ¹	Net increase (%)
	lb/tree			
GA ₃	92.2 a ²	70	67.9 a	65
Control	54.2 b		41.2 b	
	no. fruit/tree			
GA ₃	215 a	76	141 a	70
Control	122 b		83 b	

¹ Large size fruit = packing carton sizes 48+40+36.

² Values within a column followed by different letters are significantly different statistically.

Fruit Size and Yield: Irvine. In Irvine, CA, GA₃ was applied to ten-year-old ‘Hass’ avocado trees on clonal Duke 7 rootstock.

Results:

- Significantly increased total yield as pounds and number of fruit per tree by 70 percent and 76 percent, respectively (Table 3)
- Significantly increased the yield of commercially valuable size fruit (packing carton sizes 60+48+40) as pounds per tree by 65 percent and as number of fruit per tree by 70 percent (Table 3)

- Net increase in total yield of 4,180 pounds per acre (110 trees per acre)
- Net increase in commercially valuable large fruit of 2,937 pounds per acre

Since GA₃ increased total yield and yield of commercially valuable size fruit as number of fruit per tree, it is clear this treatment increased both fruit set (fruit retention) and fruit growth to increase total yield and fruit size as pounds per tree.

Table 4. Effect of GA₃ on yield and fruit size of ‘Hass’ avocado trees in Somis.

Treatment	Total yield	Net increase (%)	Valuable size fruit ¹	Net increase (%)	Large size fruit ²	Net increase (%)
lb/tree						
GA ₃	408.1 a ³	10	379.4 a	13	294.1 a	16
Control	372.6 b		335.3 b		253.3 b	

¹ Valuable size fruit = packing carton sizes 60+48+40.

² Large size fruit = packing carton sizes 48+40+36.

³ Values within a column followed by different letters are significantly different statistically.

- Net increase of 2,618 pounds per acre of commercially valuable size fruit of packing carton size 60

Summary. The results presented herein provide strong evidence that foliar application of GA₃ (12.5 fluid ounces ProGibb LV Plus®) at the cauliflower stage of inflorescence development of ‘Hass’ avocado significantly increased total yield and fruit size. Net increases in total yield ranged from 3,751 to 4,400 pounds per acre per year (110 trees per acre).

Increased fruit size was documented by the increased yield of:

- Commercially valuable size fruit of packing carton size 60
- Fruit in the combined pool of packing carton sizes 60+48+40
- Larger fruit in the combined pool of packing carton sizes 48+40+36
- Commercially valuable size fruit plus larger fruit of packing carton sizes 60+48+40+36+32

Fruit Size and Yield: Somis. In Somis, CA, GA₃ was applied to eight-year-old ‘Hass’ avocado trees on Duke 7 clonal rootstock.

Results:

- Produced significantly greater total yields (pounds per tree) and significantly greater yields of commercially valuable size fruit (packing carton sizes 60+48+40) as pounds per tree (Table 4)
- Increased the yield of large fruit (packing carton sizes 48+40+36) as pounds per tree (Table 4)
- Net increase of 3,905 pounds per acre, with a net increase of 4,851 pounds per acre of commercially valuable size fruit (packing carton sizes 60+48+40)
- Net increase in large fruit (packing carton sizes 48+40+36) of 4,488 pounds per acre

Fruit Size and Yield: Santa Paula. In Santa Paula, CA (2010-11), 11-year-old ‘Hass’ avocado trees on Duke 7 clonal rootstock were treated with GA₃.

Results:

- Significantly greater total yield (pounds per tree) (Table 5)
- Significantly greater yields of commercially valuable size fruit (packing carton size 60) as pounds per tree (Table 5)
- Net increase in total yield of 4,400 pounds per acre

Aerial Application of GA₃

The efficacy of aerial (helicopter) applications of GA₃ was tested in orchards located in Pauma Valley (40-year-old ‘Hass’ avocado trees on ‘Topa Topa’ rootstocks) and Carpinteria (four-year-old ‘Hass’ avocado trees on ‘Toro Canyon’ and ‘Dusa’ rootstocks). In each orchard, GA₃ was applied by helicopter at 25 grams of active ingredient per acre (equivalent to 12.5 fluid ounces ProGibb LV Plus®) in 25 gallons or 75 gallons of water (pH 5.5-6.0, containing 0.05 percent Silwett® L-77) per acre. Untreated control trees were used for comparison.

In Pauma Valley, GA₃ applied in 75 gallons of water per acre resulted in young fruit having significantly larger (6 percent) transverse diameters than fruit on trees treated with GA₃ applied in 25 gallons of water per acre and untreated control trees (Figure 2).

Table 5. Effect of GA₃ on yield and fruit size of ‘Hass’ avocado trees in Santa Paula.

Treatment	Total yield	Net increase (%)	Packing carton size 60	Net increase (%)
lb/tree				
GA ₃	155.2 a ¹	34	74.1 a	47
Control	115.5 b		50.3 b	

¹ Values within a column followed by different letters are significantly different statistically.

Pauma Valley

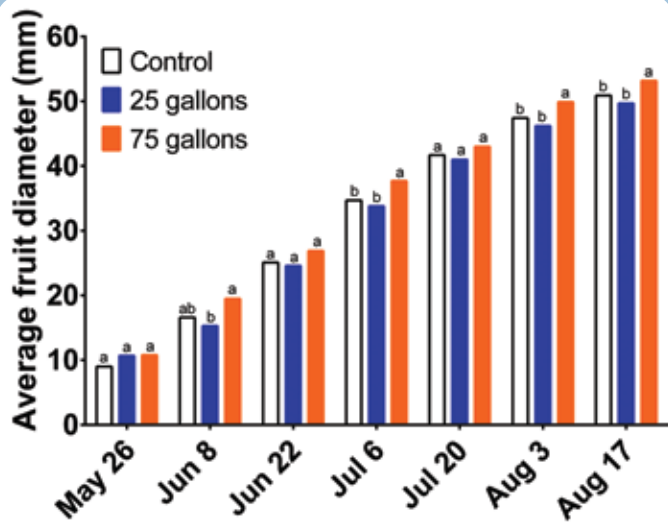


Figure 2. Effect of aerial-applied GA₃ on the diameter of young fruit (average for eight shoots per tree) at Pauma Valley. GA₃ was applied in either 25 gallons of water per acre or 75 gallons of water per acre, and a water control.

In Carpinteria, GA₃ applied in 75 gallons of water per acre resulted in young fruit having significantly greater fruit set (fruit retention; 55 percent) than trees treated with GA₃ applied in 25 gallons of water per acre and control trees (Figure 3).

Taken together the results of the aerial applications in two orchards demonstrated that GA₃ applied at the cauliflower stage of inflorescence development in 75 gallons of water per acre is efficacious in increasing fruit set (fruit retention) by 55 percent into the last week of August and fruit size by six percent through mid-August (five months after application). Increased fruit set (fruit retention) and increased fruit size are important factors in yield. The results of the aerial applications are consistent with the effects of GA₃ applied as a ground spray and indicate that 75 gallons of water per acre is the optimal volume for aerial application.

Conclusions

Foliar application of ProGibb LV Plus® to ‘Hass’ avocado trees in commercial orchards, when the trees reach the cauliflower stage of inflorescence development (typically March), significantly and reliably increases total yield and fruit size when applied at 12.5 fluid ounces per acre. This dose was superior to lower or higher doses. In addition, GA₃ had no negative effects on ‘Hass’ avocado fruit quality.

At typical prices growers receive for their crop, the yield and fruit size increases obtained in these experiments would result in substantial increases in net dollar return per acre to the grower.

Carpinteria

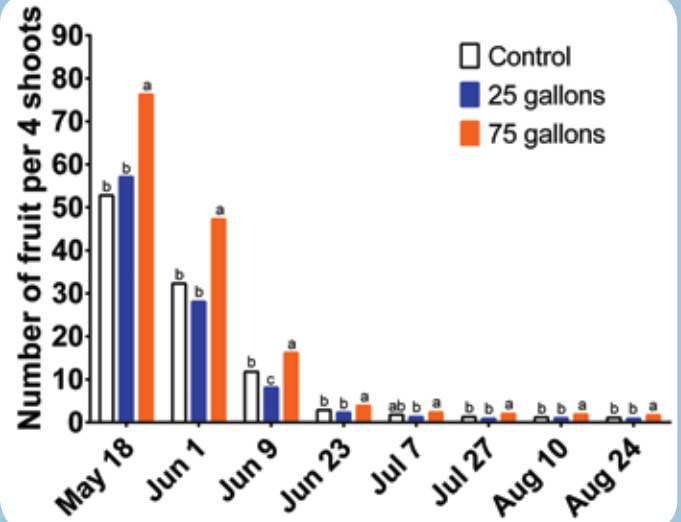


Figure 3. Effect of aerial-applied GA₃ on the retention of young fruit (number of fruit per four shoots) per tree at Carpinteria. GA₃ was applied in either 25 gallons of water per acre or 75 gallons of water per acre, and a water control.

Consistent with the results obtained with the ground sprays of GA₃, aerial applications of GA₃ at the cauliflower stage of inflorescence development also increased fruit set (fruit retention) and fruit size (diameter) at 12.5 fluid ounces in 75 gallons of water per acre. This rate was superior to 25 gallons of water per acre and untreated control trees.

Given the considerable acreage of ‘Hass’ avocado trees on slopes and in high-density plantings that are not suited to ground application, aerial application of ProGibb LV Plus® is vital to the California avocado industry to increase grower income per acre to help sustain the California avocado industry.

Acknowledgements

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