



**THE AVOCADO
QUARTERLY**

by the California Avocado Society

Winter 2021/22



ProGibb LV Plus® at the Cauliflower Stage of Avocado Inflorescence Development

A tool for increasing total yield and yield of commercially valuable size fruit

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Article Concepts

- *Yield benefits of applying gibberellic acid (GA3) to 'Hass' avocado trees at the cauliflower stage of inflorescence development (CSID)*
- *Properly timing the application*
- *Optimizing the spray solution and application to maximize efficacy*
- *Frequently asked questions*
- *Future prospects*

Yield benefits of applying gibberellic acid (GA3) to 'Hass' avocado trees at the cauliflower stage of inflorescence development (CSID)

With the cost of producing avocados increasing, growers need to increase yield and fruit size to increase net profit. Plant growth regulators (PGRs) are the most powerful tools available for achieving this goal in an existing orchard. Application of the PGR gibberellic acid (GA3) to the canopy of 'Hass' avocado trees when they are at the cauliflower stage of inflorescence development (CSID) is a valuable tool for increasing production. For example, in research trials conducted in different years in four orchards,

with trees of different ages, representing some of the different micro-climates of the avocado-growing areas of California, GA3 applied at the CSID increased total yield by an average net increase of 4,068 pounds/110 trees/acre and increased yield of commercially valuable size fruit by an average

net increase of 2,545 pounds/110 trees/acre (Fig. 1). The technology was similarly effective in a low yielding orchard-year combination resulting in less than 4,500 pounds per acre (represented by Corona), an orchard-year equivalent to the average production for California orchards of approximately 6,000

Fig. 1: Hass Yield Increases with Gibberellic Acid

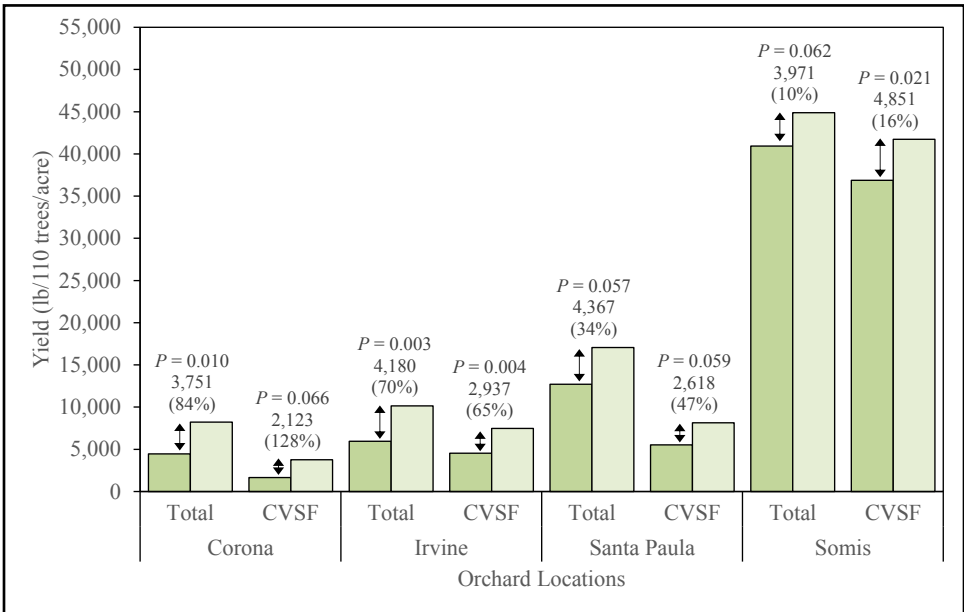


Fig. 1. Yield increases resulting from gibberellic acid (GA3) (25 g ai/acre as ProGibb LV Plus® (12.5 fluid ounces/acre) in a spray volume of 200 to 250 gallons of water/acre, containing the organosilicone surfactant Silwett L-77® or Widespread Max® (Loveland Industries, Greeley, CO) at a final concentration of 0.05% (spray solution pH 5.5 to 6.0) applied to the canopy of ‘Hass’ avocado trees at the cauliflower stage of inflorescence development (CSID). Data are the mean total yield (Total) and mean yield of commercially valuable size fruit (CVSF) (packing carton sizes: 60, 178-212 g/fruit; 48, 213-269 g/fruit; and 40, 270-325 g/fruit) for 25 untreated control trees (■) and 25 GA3-treated trees (□) in a randomized complete block design for California orchards in Corona (33°52’N, 117°34’W), Irvine (33°43’N, 117°44’W), Santa Paula (34°19’N, 119°7’W), and Somis (34°15’N, 118°59’W). Yield is expressed as pounds/110 trees/acre. Yield data for each pair of vertical columns for a given site are significantly different by Fisher’s Protected LSD test at the specified P-value; below the P-value is the net increase in yield resulting from the GA3 treatment as pounds/110 trees/acre, with the percent net increase in yield relative to the untreated control given in parentheses.

pounds per acre (represented by Irvine), an orchard-year producing approximately 12,000 pounds per acre, the production goal set for the industry by the California Avocado Commission (represented by Santa Paula), and in a high-yielding orchard-year, in which avocado production exceeded 40,000 pounds per acre (represented by Somis) (Fig. 1). For each orchard-year combination, there was a statistically significant increase not only in total yield, but also in fruit size that resulted in statistically significant net increases in yield of commercially valuable size fruit at each site (Fig. 1). Net increases in total yield and yield of commercially valuable size fruit were relatively uniform despite the large differences in yield across sites. The standard error of the mean for total yield across sites was only 115 pounds/110 trees/acre (Fig. 1). Note that when net increases in yield were expressed as a percent of the untreated control trees at each site, in each case, the percent net increase in total yield or yield of CVSF (given in parentheses in Figure 1) decreased as yield increased.

The results reported in Figure 1, and others not reported herein, including data from experiments testing the efficacy of aerial (helicopter) GA3 applications at CSID, resulted in gibberellic acid (GA3) being approved for use on avocado to increase fruit size and yield on March 27, 2018. The only material registered for this

purpose is ProGibb LV Plus®, a low volatile organic compound (LVOC) formulation, manufactured by Valent BioSciences, Corporation (Libertyville, IL). Only this product may be used; the older formulation sold under the name ProGibb® and other generic GA3 products cannot be used. ProGibb LV Plus® has a restricted entry interval of only 4 hours and a preharvest interval of 0 days. For growers producing organic avocados, it is important to note that ProGibb LV Plus® is approved for use in certified organic orchards by the Organic Materials Review Institute (OMRI).

Properly timing the application of GA3 to the cauliflower stage of inflorescence development

Gibberellic acid (GA3) as ProGibb LV Plus® is applied as a foliar spray at the cauliflower stage of avocado inflorescence development (CSID), which typically occurs in March in the southern avocado growing-areas of California (Northern Hemisphere; September in the Southern Hemisphere) (Fig. 2). Plant growth regulator (PGR) application times are based on tree phenology. The developmental stage of the target organ, the cauliflower stage inflorescence in this case, determines the result obtained in response to the PGR application. Calendar dates alert us as to when key stages of tree phenology occur in general and remind us to check developmental progress under the climatic conditions of a given

year. The cauliflower stage of the avocado inflorescence represents an important stage in avocado fruit production. The final stages of pollen development and ovule formation are occurring and 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. Research results with other plant species document that GA3 is necessary for development of the stamen, the male reproductive structure of the flower, pollen formation, and pollen viability (Chhun et al. 2007). In addition, GA3 improves pollen tolerance to cold stress (Sharma and Nayyar 2016), enhances pollen

tube growth during fertilization, and is important for subsequent seed development (Singh et al. 2002); GA3 plays a role in petal formation during flower development (Hu et al. 2008).

The application of ProGibb LV Plus® should be made when 50% of the trees in the block have 50% of their bloom at the cauliflower stage. This means that 25% of the bloom will be at an earlier stage of inflorescence development and 25% will be approaching bloom (open flowers). For the application of GA3, the cauliflower stage of inflorescence development includes the stage up to 10% inflorescence expansion (Fig. 2). If you are unable

Fig. 2: Hass Calendar of Key Development Events

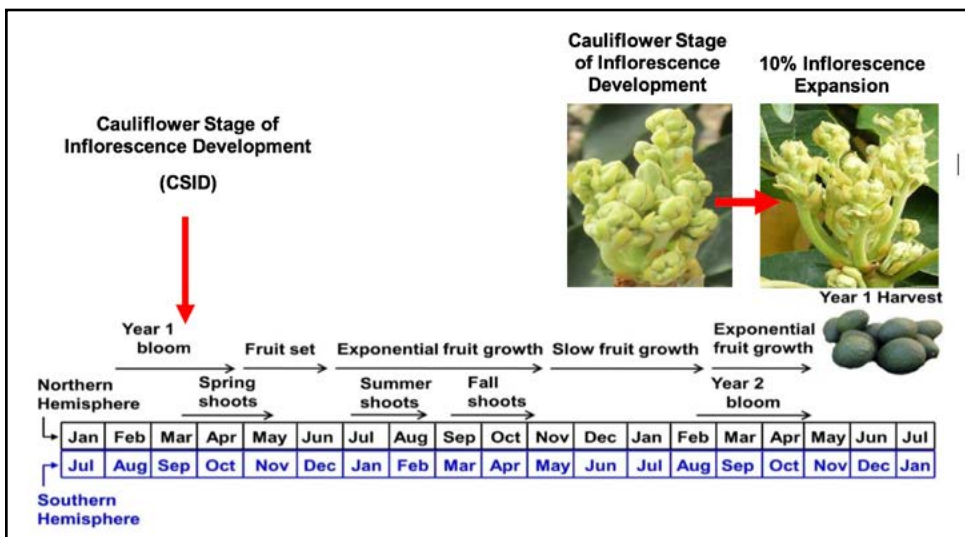


Fig 2. Calendar dates associated with key developmental events in the phenology of the 'Hass' avocado tree in the avocado growing-areas of southern California (Northern Hemisphere), with the approximate calendar dates for the Southern Hemisphere. The cauliflower stage of inflorescence development (CSID) through 10% inflorescence expansion of the 'Hass' avocado tree typically occurs in March in California (Northern Hemisphere; September in the Southern Hemisphere).

to make the application during this window, being slightly late in applying the treatment (i.e., > 25% of the inflorescences are approaching open flowers) affords better efficacy than being too early (i.e., > 25% of the inflorescences are still undergoing bud break); however, note that applications made at full bloom are generally not effective. The treatment is effective for cauliflower stage inflorescences up to 10% inflorescence expansion. The goal is to treat as many inflorescences as possible during this window of avocado inflorescence development.

Optimizing the ProGibb LV Plus® spray solution and application to maximize efficacy

Dose and Dilution Rate. The spray should be applied like a pesticide spray to give full canopy coverage, especially of the developing inflorescences, but not sprayed to run-off, which is a waste of product. For ground application, the label rate is 12.5 fluid ounces of ProGibb LV Plus® (25 grams GA3) in 100 gallons of water per acre. For aerial (helicopter) application, use 12.5 fluid ounces of ProGibb LV Plus® in 75 gallons of water per acre. The maximum allowable dose of ProGibb LV Plus® is 12.5 fluid ounces (25 g GA3) per acre per year. The results from multiple dose response experiments with ground and aerial applications 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 5.0 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 GA3 to a pH > 8.5 should be avoided as it can cause the breakdown of the GA3 molecule.

Spray Volume. For ground applications, we used GA3 in 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.

The spray volume on the ProGibb LV Plus® label is 100 gallons of water per acre. Use of spray volumes greater than label rate 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® at 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.

Answers to frequently asked questions

Can boron, nitrogen or other nutrients be included in the ProGibb LV Plus® spray solution?

Previous research has shown that combining two simple fertilizers, boron (sodium borate) and nitrogen (low-biuret urea) to 'Hass' avocado trees at the cauliflower stage of inflorescence development resulted in double pistils, each with an ovule (seed). Thus, at this time, we recommend that other materials not be included in the ProGibb LV Plus® spray solution. Both the author and the California Avocado Commission are testing the efficacy of ProGibb LV Plus® combined with boron or low-biuret urea, respectively, and will share the 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 the avocado inflorescence 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.

Is there a benefit from applying GA3 at the cauliflower stage of inflorescence development to mature fruit on the tree before harvest?

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, reduce preharvest fruit drop and slow the blackening of the peel of mature fruit on the tree at the time of application. These results are not achieved annually because the outcome is dependent on crop load and how long the fruit remain on the tree after treatment until harvested. Note that ProGibb LV Plus® is exempt from the determination of a maximum residue level (MRL) and has a preharvest interval of 0 days.



Does applying GA3 at the cauliflower stage of inflorescence development affect fruit quality of the setting crop or mature fruit?

GA3 treatment had no negative effects on quality of mature fruit or quality of the fruit that developed from the treated bloom. GA3 application had no effect on the number of days 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, the 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. In some years, GA3 kept the peel of the mature fruit on the tree at the time of application from turning black without affecting the number of days to "eating soft". In addition to increasing fruit set and size of fruit set by the treated inflorescences, GA3 stimulated the elongation of the terminal vegetative shoot of indeterminate inflorescences, increasing the rate at which leaves transitioned from sinks

competing with setting fruit for resources to sources contributing resources to the developing fruit. Additionally, the advanced elongation of vegetative shoots and expansion of leaves shaded the developing fruit, protecting them from sun burn damage.

Does GA3 applied at the cauliflower stage of inflorescence development in an alternate bearing orchard exacerbate or mitigate alternate bearing?

Our research results indicate that GA3 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. Repeated measure analysis was used to determine statistically whether the yield increase resulting from GA3 application at the cauliflower stage of inflorescence development to ON-bloom 'Hass' avocado trees reduced yield the following year. Specifically, did GA3 applied at the CSID in the ON-crop year make the OFF crop more OFF? Despite large differences in yield between the two crop years in this experiment (7,634 vs. 1,606 pounds/110 trees/acre), GA3 applied at the CSID as prescribed above significantly increased yield and fruit size when averaged across both years of the experiment. Compared to the untreated control tree,

GA3 significantly increased the two-year average total yield expressed as pounds/110 trees/acre by 51 percent and as number of fruit/110 trees/acre by 60 percent. Moreover, GA3 increased the two-year average yield of CVSF (packing carton sizes 60+48+40; 178-325 g/fruit) as pounds/110 trees/acre by 47 percent and as number of fruit/110 trees/acre by 51 percent compared to the yield of untreated control trees for the two-year alternate bearing cycle. These results provide evidence that the response to GA3 was positive in both the ON and OFF crop years of the experiment, although the greatest increases in total yield and yield of CVSF were achieved in the ON year due to the significantly great number

of inflorescences at bloom. The data documented that GA3 application during an ON-bloom year did not exacerbate alternate bearing but instead increased both yield and fruit size in both the ON- and OFF-crop years, which helped to mitigate the negative effect of alternate bearing on grower income.

Can ProGibb LV Plus® be used in organic avocado orchards?

ProGibb LV Plus® is National Organic Program compliant and is registered with the Organic Materials Review Institute (OMRI). The current OMRI certificate can be downloaded from the Agrian data-base (home.agrian.com).

Fig. 3: Fruit Size Distribution

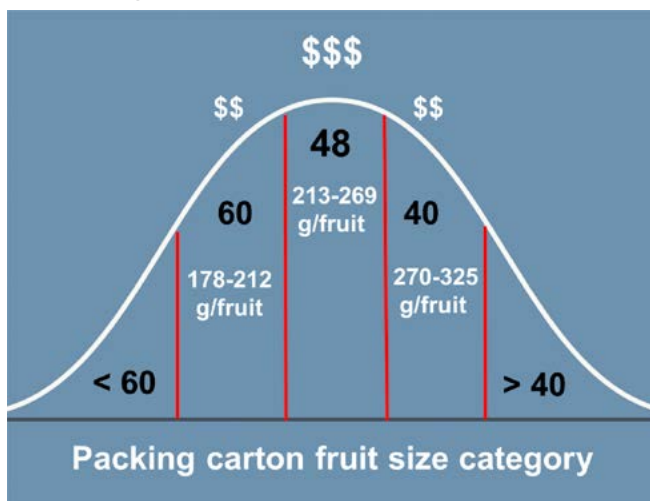


Fig. 3. Normal fruit size distribution for packing carton sizes 60+48+40 for the Hass avocado in California.

Future prospects

The Special Local Needs label that currently makes the use of GA3 on avocado trees in California possible is good through March 2023. Valent BioSciences is in the process of placing this avocado use pattern on their ProGibb LV Plus® production label. Through 2021, GA3 has been used on less than 15% of the bearing avocado acreage in California. The treated acres for California from 2018 through 2021 are: 2018, 1,387; 2019, 6,964; 2020, 6,057; and 2021, 5,326. According to the survey conducted by Tim Spann (2020), Research Director for the California Avocado Commission, 86% of growers who used the technology in 2018 and 2019 reported that they were satisfied with the outcome and planned to continue using ProGibb LV Plus® in their orchards. Growers who reported not being satisfied identified difficulty in timing the application and lack of results as issues. When normal weather patterns are disrupted, resulting in earlier and protracted blooms, it is difficult to determine the best time to spray. Early bloom, which will likely encounter subsequent unfavorable weather conditions, should not be treated. It is preferable to wait for the later part of the bloom that develops when the climate is more favorable for

fruit set and development. When in doubt, the goal should be to spray as large a cohort of cauliflower stage inflorescences as possible under potentially better climate conditions to increase set fruit and fruit size. Note that use of GA3 at the CSID is not yet registered outside of the United States.

Conclusion

Foliar application of GA3 as ProGibb LV Plus® to 'Hass' avocado trees in commercial orchards when the trees reach the cauliflower stage of inflorescence development (typically March), like its earlier formulation ProGibb®, significantly and reliably increased total yield and fruit size when applied at 25 g active ingredient (12.5 fluid ounces of ProGibb LV Plus®) per acre. This dose was confirmed to be superior to lower or higher doses in multiple dose-response experiments with ground and aerial applications. In addition, GA3 had no negative effects on 'Hass' avocado fruit quality in any experiment. 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) using 12.5 fluid ounces of ProGibb LV Plus® in 75 gallons of water per acre. 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. At typical prices growers receive for their crop, the yield and fruit size increases obtained in the experiments reported herein would result in substantial increases in net dollar return per acre to growers.

Acknowledgements

This research was supported in part by the University of California Citrus Research Center and Agricultural Experiment Station and by grants from the California Avocado Commission. A special thank you to the following for the use of their orchards and for their assistance with harvest: Corona Foothill, Inc.; Jesus Ruiz, Irvine Co.; Gus Gunderson, Limonera, Co.; Charles and David Vanoni, Rancho Bella Vista; Rick Shade, Shade Farm Management; and Chuck Bandy, McMillan Farm Management. Additional thanks to Toan Khuong, Associate Research Specialist, for statistically analyzing the data; Rob Fritts, Valent BioSciences, for donating the ProGibb® and ProGibb LV Plus®; and to Bob Hoag, Hummingbird Helicopters, and Kevin Miskel, Aspen Ag Helicopters, who made the aerial applications.

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