

## **Carol J. Lovatt**

Professor of Plant Physiology

Department of Botany and Plant Sciences

University of California, Riverside

## **Alternate Bearing Of ‘Hass’ Avocado**

*A summary of basic information to assist growers in managing their orchards*

### *Concepts reviewed in this summary –*

- The problem of alternate bearing.
- Fruit influence avocado tree phenology and return bloom and yield.
- Summer vegetative shoot growth is key to a good return bloom and yield.
- The setting ON crop of fruit inhibits summer vegetative shoot growth.
- The setting ON crop of fruit has a localized and whole tree effect on return bloom.
- The number of shoots that do not set fruit during the ON-crop year is important.
- The effect of the ON crop on return bloom is cumulative.
- Year 1 mature avocado fruit do not influence flower and fruit abscission in Year 2.
- Strategies growers can use now to mitigate alternate bearing.
- We are all in this together, share results!

*The problem of alternate bearing*

Alternate bearing (also called biennial or uneven bearing) is the tendency of a fruit tree to produce a heavy, high yield “ON crop” (ON tree, ON year) followed by a light, low yield (or no crop) “OFF crop” (OFF tree, OFF year). The ON year is initiated with an intense ON bloom that sets the ON crop, whereas the OFF year is initiated with a sparse OFF bloom that sets the OFF crop. The phenomenon is widespread, occurring in both deciduous and evergreen trees under commercial production and in nature, where it is called “masting” (Monselise and Goldschmidt, 1982). Alternate bearing can occur over a large geographical area, an entire grove, an individual tree, part of a tree or even for one branch (Monselise and Goldschmidt, 1982).

Alternate bearing has a severe negative economic impact on the commercial avocado industry. The ON crop is characterized by a large number of small-sized fruit of reduced commercial value at harvest. For the OFF crop, fruit size is large but there are too few fruit to provide the grower with a good income. Annual yield and crop value data for the California avocado industry summarized in Table 1 reflect the reduced cash value of the ON-crop fruit and the limited revenue generated by the OFF crop. The data in Table 1 document that alternate bearing ‘Hass’ avocado orchards suffer a measurable loss in profitability in both the OFF- and ON-crop years. In addition, the reduced amount of fruit in the OFF year can result in a loss of market share and threaten the sustainability of the fresh fruit industry. Years with low fruit volume can compromise the development and sustainability of value-added product industries. Furthermore, alternation in crop load complicates orchard management.

Table 1. California avocado industry yields (lbs) and crop value (US\$) per bearing acre.<sup>2</sup>

Year	Yield (lbs)	Crop Value (US\$)
----- per bearing acre -----		
2003/2004	7,129	6,272
2004/2005	4,868	4,457
2005/2006	9,677	5,495
2006/2007	3,989	3,768
2007/2008	5,028	4,995
2008/2009	2,703	3,092
2009/2010	9,173	6,912

<sup>2</sup> <http://www.Californiaavocadogrowers.com/industry-statistical-data>.

Keep in mind that the impact of alternate bearing on individual growers is more dramatic than the California avocado industry averages reveal. The alternate bearing index (ABI) reflects the severity of alternate bearing in an orchard. In its simplest form, ABI can be calculated by subtracting the yield for the OFF-crop year from the yield for the ON-crop year and dividing the difference by the sum of the ON and OFF yields. When ABI is 1.0, alternate bearing is 100% (i.e., crop one year, no crop the other year) and when ABI is 0, there is no alternate bearing (Pearce and Dobersek-Urbanc, 1967). Typical ABI values for ‘Hass’ avo-

cado orchards in California are between 0.57 and 0.97, which indicates that yield is 60% to 100% less in the OFF-crop year compared to the ON-crop year.

The problem of alternate bearing reoccurs because the major factors initiating alternate bearing are recurring climatic events. Alternate bearing is typically initiated by freeze, low or high temperatures, or water-deficit stress during bloom or fruit set, which result in low flower number or cause excessive flower and/or fruit drop. This results in an OFF crop, which is typically followed by an ON crop the next year, depending on how long it takes the trees to recover. Alternate bearing can also be triggered by under fertilization and irrigation, resulting in excessive flower and fruit abscission, or by over pruning, resulting in low flower or fruit number and excessive vegetative shoot growth. These conditions result in an OFF crop that will be followed by an ON crop. Conversely, optimal conditions for bloom and fruit set such that natural fruit thinning fails to take place result in an ON crop followed by an OFF crop. Once initiated, alternating ON/OFF cycles are perpetuated by the effect of fruit number (crop load) on factors within the tree that ultimately impact floral intensity the following year. Thus, an ON bloom sets and matures an ON crop that causes a low floral intensity OFF bloom and OFF crop the following year, whereas the OFF bloom sets and matures an OFF crop that results in an intense ON bloom the next spring. Since climate is a major factor initiating alternate bearing, the need for a solution to the problem of alternate bearing is frequent, but the need to culturally manage alternate bearing is almost annual.

### *Fruit influence avocado tree phenology and return bloom and yield*

In recent research, the effects of the OFF crop, the ON crop and removing the entire ON crop on 'Hass' avocado tree phenology, vegetative shoot growth, floral development and the next year's yield under California growing conditions were quantified. The results of this research provide insight into solutions to alternate bearing that can be used now. In addition the results identified the best time for taking action and established the consequences of delaying action or doing nothing.

For the sake of this discussion, Year 1 starts with bloom. The ON crop (ON year) is initiated with an intense ON bloom, followed by the setting of the ON crop of fruit. We will follow the Year 1 ON crop from fruit set through development to harvest to discuss how and when the ON crop of fruit at each stage of development impacts avocado tree phenology and return bloom and yield the following year (Year 2). To facilitate comparison of the effects of ON and OFF avocado crops, we will similarly discuss the effects of the OFF crop of fruit on avocado phenology starting with the Year 1 light OFF bloom, which sets the OFF crop.

*Summer vegetative shoot growth is key to a good return bloom and yield*

**OFF-bloom/OFF-crop Year.** When the avocado tree sets and develops an OFF crop, a significant number of vegetative shoots develop during the summer and to a lesser degree during the fall of Year 1 (Fig. 1). The following spring, it is the Year 1 summer shoots that contribute the greatest number of floral shoots (inflorescences) to bloom, resulting in the ON bloom and ON crop in Year 2. For OFF-crop ‘Hass’ avocado trees in California, ~75% of the Year 2 floral shoots are produced by the Year 1 summer vegetative shoots, ~15% by the Year 1 spring vegetative shoots and ~10% by Year 1 fall vegetative shoots. Note that Year 1 summer shoots produce ~80% of the determinate floral shoots that contribute to making Year 2 an ON bloom (Lovatt, 2004, 2005, 2006). Determinate floral shoots, which are more productive than indeterminate floral shoots, are produced by the apical and axillary (lateral buds) borne in the axil of the leaves along the length of summer vegetative shoots. Fall shoots that flower produce only a single terminal indeterminate floral shoot (Salazar-García and Lovatt, 1998). Thus, summer vegetative shoot growth is key to a good return bloom; the more summer vegetative shoots, the greater the return bloom and yield.

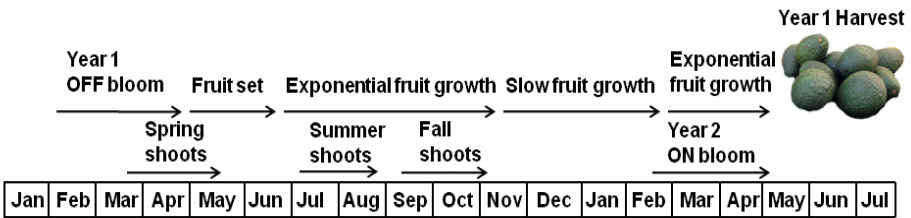


Fig. 1. An OFF-crop year starts with an OFF bloom that sets an OFF crop or is initiated by a climatic or culture event that reduces flower or fruit number during the bloom or fruit set periods. The low number of young developing fruit in Year 1 results in a significant amount of summer and fall vegetative shoot growth that contributes floral shoots to the ON bloom in Year 2, ~75% and ~10% by summer and fall shoots, respectively. Summer vegetative shoots also contribute the majority of determinate floral shoots, which are present in high numbers only in an ON bloom. Note that the mature fruit of the OFF crop are fewer in number but large in size.

*The setting ON crop of fruit inhibits summer vegetative shoot growth*

**ON-bloom/ON-crop Year.** During Year 1, the ON crop of young developing fruit inhibits summer and fall vegetative shoot growth, thereby reducing the number of buds that can produce floral (and vegetative) shoots the next spring, resulting in an OFF bloom (Year 2) (Fig. 2). Note that due to the inhibition of summer vegetative shoot growth during the ON-crop year, there are few to no determinate floral shoots at spring bloom in Year 2 and the majority of the floral shoots that do develop are produced by the Year 1 spring shoots.

The importance of summer and fall shoots to the floral intensity of bloom in Year 2 was confirmed by removing all summer and fall shoots from OFF-crop ‘Hass’ avocado trees during Year 1 and comparing the return bloom and return yield of these trees to untreated OFF-crop control trees. At return bloom the

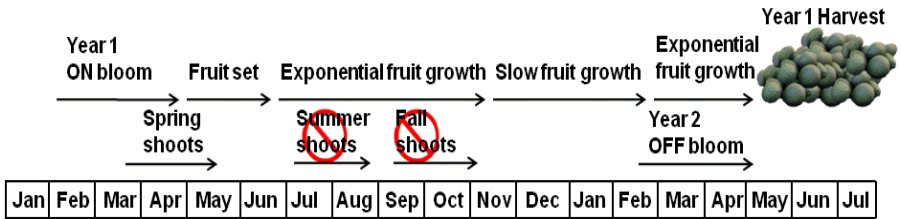


Fig. 2. An ON-crop year starts with an ON bloom that sets an ON crop or is initiated by climatic or culture events that are optimal for flowering and fruit set such that natural fruit thinning fails to take place. The large number of young developing fruit inhibits summer and fall vegetative shoot growth. The loss of summer and fall shoots means there are fewer sites that can bear floral shoots in spring of Year 2, especially determinate floral shoots, which develop predominantly on summer shoots. The result is an OFF bloom in Year 2 that is produced predominantly by the Year 1 spring shoots. Note that there are many smaller mature fruit in the ON crop.

following year, untreated OFF-crop control trees flowered profusely, whereas OFF-crop trees with summer and fall shoots removed had a weak bloom and low return yield (2 kg/tree in Year 2) (Lopez-Jimenez and Lovatt summarized in Lovatt, 2005). From these data it is clear that summer vegetative shoot number is key to a good return bloom and yield and that the ON crop of fruit reduces summer vegetative shoot growth and thus, return bloom and yield.

***The setting ON crop of fruit has a localized and whole tree effect on return bloom***

On both ON- and OFF-crop avocado trees, some Year 1 spring shoots set fruit (+fruit) and others fail to set fruit (-fruit). Clearly ON-crop trees have more shoots that set fruit (+fruit) than OFF-crop trees. In Year 1, four shoots (one in each quadrant of the tree) that set fruit (+fruit) and four shoots that did not set fruit (-fruit) on ON- and OFF-crop ‘Hass’ avocado trees were tagged. At bloom the following year, the number of floral shoots produced by each tagged shoot was counted. Year 1 shoots (+fruit) on ON-crop trees produced the least floral shoots (Table 2). Year 1 spring shoots (-fruit) on ON trees and Year 1 shoots (+fruit) on OFF trees produced an intermediate number of floral shoots. Year 1 shoots (-fruit) on OFF trees produced the most floral shoots at return bloom. Note in Table 2 that for shoots (-fruit) on OFF-crop trees, it is the summer (and fall) shoots that contributed the majority of floral shoots to return bloom.

***The number of shoots that do not set fruit during the ON-crop year is important***

Table 2 data clearly illustrate the interaction between the localized effect of fruit present on a shoot and the whole tree effect related to crop load. These interactions are strongest and least variable for buds on Year 1 spring shoots (-fruit) on OFF trees and Year 1 spring shoots (+fruit) on ON-crop trees. The data reveal that the full negative effect of fruit on return bloom in alternate bearing is expressed on spring shoots that set fruit (+fruit) on ON-crop trees. Note that for ON- or OFF-crop trees, the greater intensity of the return bloom, and hence the yield obtained in Year 2 will be proportional to the number of shoots that do not set fruit (-fruit) in Table 2. Contribution of Year 1 spring and summer plus Year 1. This is an important concept for managing alternate bearing. Both Growers A and B have 400 fruit per tree. Grower A's crop will be followed by an OFF bloom and OFF crop but Grower B's crop will be followed by another crop of 400 or more fruit per tree. *Why?* Because Grower A has very few shoots without fruit (-fruit) that can produce vegetative shoots in summer and floral shoots the next spring, whereas Grower B has more than 400 shoots without fruit (-fruit) that will produce summer (and fall) vegetative shoots and a strong bloom with determinate floral shoots in addition to indeterminate floral shoots the following spring.

	Total	Spring	Summer + Fall
	----- no. floral shoots/4 shoots -----		
Shoots+fruit			
ON tree	0.30 c <sup>z</sup>	0.20 c	0.10 b
OFF tree	1.70 bc	0.70 bc	1.00 b
Shoots-fruit			
ON tree	4.20 b	2.30 a	1.90 b
OFF tree	10.15 a	1.90 ab	8.25 a
P-value	<0.0001	0.0076	<0.0001

<sup>z</sup> Values in a vertical column followed by different letters are significantly different at the P-value specified by Fisher's Protected LSD Test.

***The effect of the ON crop on return bloom is cumulative***

A fruit removal experiment was conducted to determine when the ON crop is exerting its effect on the return bloom. This basic information is necessary for timing treatments to mitigate alternate bearing. The results demonstrated that the effect of the ON crop on return bloom is cumulative. In this experiment, all fruit were removed from sets of ON-crop trees in progressively later months

of the year. The intensity of the return bloom on these trees was compared to OFF- and ON-crop control trees. For this experiment, only the setting ON crop of fruit was present on the trees, i.e., the previous year's mature crop had been harvested before June. Removing all Year 1 young developing fruit from ON-crop trees in June, July or August significantly increased the number of summer and fall vegetative shoots that developed and the intensity of the Year 2 bloom and yield to values greater than or equal to the return bloom and yield of Year 1 OFF-crop control trees, which were now ON-crop trees in Year 2. Removing fruit progressively later (from September through December), reduced the number of summer vegetative shoots that developed, followed by a reduction in the number of fall vegetative shoots that developed. This reduced the respective contributions of summer and fall shoots to spring bloom compared to OFF-crop control trees or ON-crop trees with all fruit removed in June, July or August. Removing fruit as late as December increased the number of floral shoots contributed by the Year 1 spring shoots during bloom in Year 2 compared to ON-crop control trees with no fruit removed, demonstrating that Year 1 spring shoots had viable floral buds through December. However, the number of floral shoots that developed on ON-crop trees with the fruit removed in December was significantly less than OFF-crop control trees and ON-crop trees with their fruit removed earlier in the year, which had produced summer and/or fall vegetative shoots that contributed to return bloom. Moreover, in this experiment, there was an incremental decrease in floral shoot number on Year 1 spring shoots for each month the ON crop remained on the trees past December compared to OFF-crop control trees and ON-crop trees with all fruit removed in December or earlier. Moreover, leaving the ON crop of mature fruit on the tree through the summer and fall (until late October) of Year 2 had a negative effect on return bloom and yield equal to that of the young developing fruit of the ON-crop (Fig. 3). Having two crops of fruit on the tree increases the total number of shoots with fruit, reducing the number of summer vegetative shoots that develop in Year 2 and thereby reducing the return bloom of Year 3!

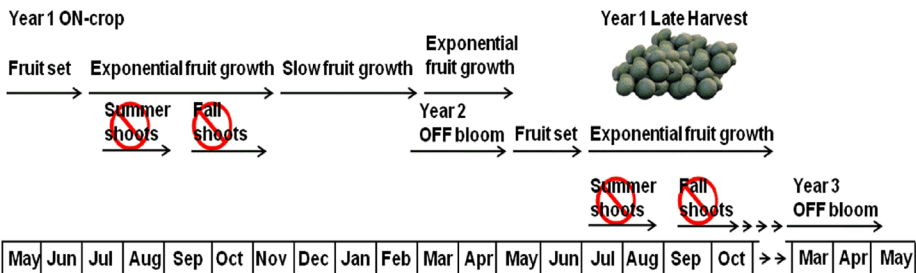


Fig. 3. Holding the mature ON crop of fruit on the tree through the summer or fall of Year 2 reduces summer and fall vegetative shoot growth of Year 2, respectively, which will reduce the Year 3 bloom, resulting in back-to-back OFF crops.

### *Year 1 mature avocado fruit do not influence flower and fruit abscission in Year 2*

The fact that maturing 'Hass' avocado fruit remain on the tree past bloom and can be held on the tree through October in California raised the question of whether the number of mature fruit on the tree influences the number of reproductive structures (flowers and young fruit) that abscise (drop off) during the following year. Our results (Garner and Lovatt, 2008) demonstrated that the OFF- or ON-crop status of the tree did not influence the percent fruit set or average fruit diameter or weight of individual fruit that dropped at similar stages of development. Furthermore, the number of mature fruit in the Year 1 crop did not influence the number of flowers or young fruit that dropped in the Year 2 crop. In both years of the research, as immature fruit drop declined, abscission of the preceding year's crop (mature fruit) increased, indicating the processes were controlled independently and not driven by crop load. The results provided clear evidence that the previous year's crop load does not influence current year flower or fruit drop of 'Hass' avocado. Thus, the seasonal shedding of reproductive structures is an independent process that, in the absence of climatic triggers, is not a factor contributing to alternate bearing.

### *Strategies growers can use now to mitigate alternate bearing*

In many of foreign countries, 'Hass' avocado growers are able to use plant growth regulators (PGRs) not available to California growers to manipulate flowering and yield. For California avocado growers to remain competitive, yield following the heavy ON crop must be increased substantially to even out successive annual yields and to stabilize grower profitability. California avocado growers prefer a cost-effective strategy that does not require fruit removal during the ON-crop year to mitigate the negative effects of the ON crop and increase yield the following year to sustain their farms and the industry. Growers rightfully consider flower and fruit removal risky and expensive. Thus, we are currently conducting research supported by the California Avocado Commission to develop PGR strategies that mitigate the effect of the ON crop to increase return bloom and yield the following year with the goal of not having to remove fruit during the ON-crop year. Our PGR research is long-term. In July 2012, we will begin testing the efficacy of foliar- and irrigation-applied PGRs to mitigate alternate bearing by treating trees setting an ON-crop, with the goal of increasing the floral intensity of the putative OFF bloom in spring 2013 and the yield of the 2013-2014 crop. The success of the treatments will be evaluated after the harvest in July 2014.

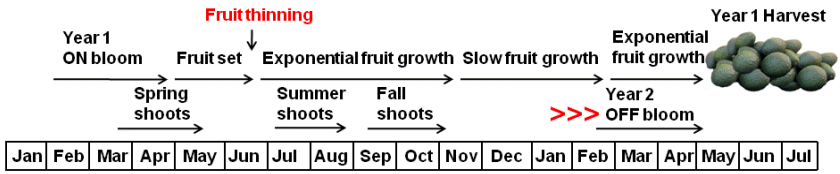
In the meantime, growers can take actions that will mitigate the effects of the ON crop to improve annual income. Please note that the more effective strategies are also more risky. Both the benefit and risk depend on the degree to



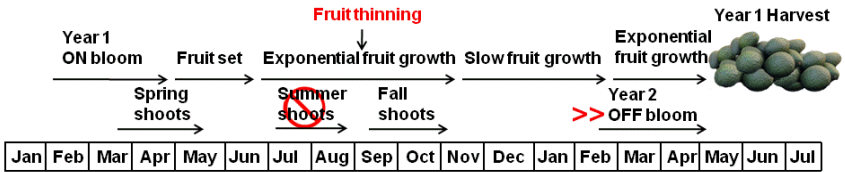
which a strategy is imposed and how early in the fruiting cycle that action is taken. For example, reducing floral shoot number is very risky versus early harvest of fully mature fruit. In deciding when to act, it is important to remember that the results of the fruit removal experiment provided evidence that the negative effect of the ON crop on return bloom and yield is cumulative. Thus, while delaying fruit thinning may be safer with regard to the current crop (Year 1), the negative consequences on the Year 2 bloom and yield are clear. For many strategies, there is no proven formula for implementation. Growers will have to learn by doing. The information above and discussion below provide growers with the critical background information and guiding principles to make wise decisions in managing their alternate bearing acreage.

Reducing bloom going into an ON-crop year. If your trees need to be pruned, selectively pruning branches without fruit, to the degree possible, during the winter of the OFF-crop year will reduce the intensity of the putative ON-bloom while preserving the light OFF-crop. By waiting to prune during the actual ON bloom, it is easier to gauge the degree of floral shoot removal required and to distribute the remaining floral shoots, and resulting crop, more uniformly over the tree while preserving the OFF crop. Results of on-going research in New Zealand suggest that three out of every ten floral branches could be removed in the ON-bloom year to reduce crop load in the ON year and thus, increase the number of floral shoots the following year (Jonathan Dixon, personal communication).

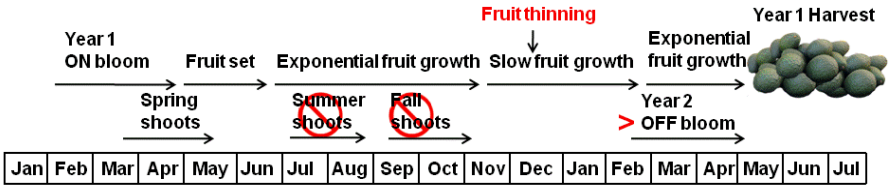
Strategies for thinning and harvesting the ON crop. Thinning (fruit removal by hand) the ON crop prior to summer vegetative shoot growth is the most effective time for increasing return bloom and yield in Year 2 (Fig.4A). Summer fruit thinning is also the optimal time for increasing the size of the young developing fruit. Thinning the ON crop prior to fall shoot growth will increase return bloom and yield, but not as much as summer fruit thinning (Fig. 4B). The Year 1 ON crop has to be thinned by December (typically before legal maturity) of Year 1 or earlier to have a positive effect on Year 2 bloom and yield (Fig. 4C). Removing as much of the mature (Year 1) ON-crop as possible as early as possible by size picking combined with harvest of the remaining crop before summer vegetative shoot growth (July<sup>†</sup>) reduces the probability of having two OFF crops in a row (Fig. 3). Neither strategy influences the Year 2 bloom or yield.



A.



B.



C.

Fig. 4. A. Thinning (fruit removal by hand) the ON crop in early summer has the greatest potential to increase the number of summer and fall vegetative shoots that develop and thus, the greatest potential to significantly increase floral intensity and yield above that of the expected Year 2 OFF bloom and OFF crop. Summer fruit thinning is also the optimal time for increasing the size of the young developing fruit. B. Thinning the ON crop in fall will reduce the number of summer vegetative shoots that develop and their contribution to return bloom and yield, but will preserve the growth of fall vegetative shoots and their contribution to increasing Year 2 bloom and yield above the anticipated OFF bloom. C. Waiting until December to thin the ON crop will eliminate the contribution that summer and fall vegetative shoots could make to the Year 2 bloom, but will increase the contribution made by the Year 1 spring vegetative shoots so that bloom and yield in Year 2 will be slightly greater than the putative OFF bloom and OFF crop.

The setting fruit of the ON crop can be removed by hand or by pruning. In either case, the goal is to reduce the number of fruit in the ON crop uniformly over the tree sufficiently early to promote summer vegetative shoot growth. Fruit removal by hand is the best and safest approach. Clusters of fruit can be thinned to increase fruit size, small fruit that are not likely to reach commercial size can be removed, damaged fruit can be eliminated, and fruit removal can be done so that the remaining fruit are uniformly distributed over the tree. Research in a commercial ‘Hass’ avocado orchard in Carpinteria, California, provided evidence that fruit drop of the young, developing fruit is minimal by the third week of

August in both ON- and OFF-crop years (Garner and Lovatt, 2008). If fruit are being removed by hand, it is possible to wait until this time to thin the crop, which will reduce the risk associated with high temperatures that can occur during the June drop period (mid-June through the end of July) and increase return bloom to a greater degree than fall fruit thinning would accomplish. If the crop is to be thinned by pruning, prune with caution. The goal is a light pruning for crop management to promote summer vegetative shoot growth. It must be done sufficiently early (spring or early summer) so the new vegetative shoots have time to mature and develop floral buds. Fall pruning will not significantly increase return bloom. Pruning off summer shoots from spring shoots that did not set fruit (shoots without fruit) defeats the purpose. Start small and see how your trees respond. There are rumors that trees pruned in July or August developed no floral shoots on the regrowth at spring bloom. Avoid over-pruning, which will interfere with floral bud development. When deciding how many fruit to remove or how much to prune from ON-crop trees, keep in mind that next year's crop will be produced predominantly on Year 1 (current season) summer shoots produced by spring shoots that did not set fruit (without fruit) or from which fruit have been removed by hand or pruning. In addition to pruning to reduce crop load, pruning should be done at other times of the year to increase shoot number (the amount of fruiting wood) and branching (tree complexity), which contribute to increased floral shoot number and yield the following year.

Fertilizer strategies. Our understanding of best management fertilization practices (BMPs) for an alternate bearing 'Hass' avocado orchard would definitely benefit from additional research. However, there are practices with known benefits that should be considered. During the OFF bloom, canopy-applied boron [1.3 lbs/acre B as 6.3 lbs/acre Solubor (20.5% B)] or nitrogen [23 lbs/acre N as 50 lbs/acre low-biuret urea (46% N, 0.25% biuret)] at the cauliflower stage of inflorescence development can be used to increase fruit set. For 'Hass' avocado, a canopy application of B or urea-N at the cauliflower stage of inflorescence development significantly increased the number of viable ovules, increased the number of pollen tubes that reached the ovule, and increased total yield and yield of commercially valuable fruit (packing carton sizes 60 + 48 + 40) (Lovatt, 1999). The application is made when 50% of the trees in the block have 50% of the bloom at the cauliflower stage, 25% will be at an earlier stage of inflorescence development and 25% will be approaching or at full bloom (open flowers). Earlier (bud break) applications were not effective, later (full bloom) applications were intermediate in effect. Boron is also known to stimulate cell division and increase fruit set and fruit size of many crops, even seedless fruit, and even when leaf analyses indicate B is adequate. Boron is preferred over urea-N due to the potential negative effect that can occur when air temperatures reach 90 °F or above after spraying. Late

afternoon or early evening sprays are best; morning sprays are fine as long as the temperature remains moderate throughout the day. The spray should target the inflorescences. Boron is more effective when applied directly to the flowers; urea is not taken up by mature leaves of avocado trees grown in California but is taken up by flowers (Nevin et al., 1990). Do not apply both boron and urea together in the same spray! The effect of applying boron and urea separately in the same season is not known.

Growers should fertilize their trees to meet the total demands of the tree throughout the development of the fruit, including maturing fruit, floral shoots, setting fruit, young fruit during exponential growth, and summer vegetative shoots, which contribute the greatest number of floral shoots to bloom. Not only is matching the amount of fertilizer applied to tree nutrient demand cost-effective, it also protects the environment, especially our water resources. Early research (Lovatt and Witney, 2001) provided evidence that 'Hass' avocado trees in California required 90 lbs N per acre to produce 11,000 lbs of fruit per acre with a 10% increase in vegetative shoot and root growth and sufficient N to accommodate volatilization and leaching. The calculation did not take into account the N requirement of the Year 2 bloom or young developing fruit. Thus, if used as a guide for fertilization, it underestimates N demand. With recent ON crops exceeding 11,000 lbs per acre, N might be too low during the ON year in many orchards to support adequate summer vegetative shoot growth for a good return bloom. Consistent with this, applying 50 lbs of N (as ammonium nitrate) per acre to the soil during the period of full bloom, fruit set, and vegetative shoot growth (~mid-April) reduced alternate bearing and increased yield and fruit size of 'Hass' avocado trees receiving this treatment for the 4 years of the experiment compared to trees receiving only 25 lbs of N per acre at this time (Lovatt, 2001). Similarly, 25 lbs of N (as ammonium nitrate) applied to the soil in July and August, when exponential fruit growth, summer vegetative shoot growth and transition of buds from vegetative to floral development occur, significantly increased total yield and yield of commercially valuable fruit (packing carton sizes 60 + 48 + 40) compared to trees receiving only 25 lbs per acre in August. The N fertilizer rates reported here are not prescriptive, but illustrative of the yield benefit derived by meeting tree nutrient demand at these key stages in 'Hass' avocado tree phenology compared to not meeting the tree's N demand at these times. The amount of fertilizer to be applied is dependent on yield, canopy size, and tree and soil nutrient reserves based on leaf and soil nutrient analyses. In addition, irrigation water can contain significant amounts of essential nutrients, which should be factored into a grower's fertilization program. Note that the fertilization goal for the ON-crop year is to provide adequate fertilizer to support the developing crop and support summer vegetative shoot growth.

Recent research (Rosecrance, Faber and Lovatt, 2011) showed that 'Hass' avocado fruit number (crop load) drives N uptake, as well as the uptake of other nutrients, which parallel fruit dry weight accumulation. The tree takes up 50% of its total N from full bloom to approximately October, takes up little N during most winters, and then takes up the remaining 50% the following spring from bud break (~ mid-February) until just before harvest. With funding from the California Department of Food and Agriculture Fertilizer Research and Education Program, Dr. Richard Rosecrance, Professor of Plant Science, California State University-Chico, is creating a web-based decision support system (DSS) that will enable growers to calculate the fertilizer needs of their trees based on the yield of the mature and setting crops in the orchard, tree size, planting density, tree nutrient status and additional factors. In the meantime, by estimating the yield of the Year 1 crop of mature fruit and yield of the Year 2 crop of setting fruit and using the rate of 90 lbs of N per 11,000 lbs of fruit per acre as a reference, one can calculate the approximate total N that will be required to produce each crop, keeping in mind that 50% should be applied to the Year 1 mature fruit from bud break until just before harvest, whereas the Year 2 setting crop should receive 50% of the total N required beginning at full bloom through October, with a significant portion (a minimum of 20-25 lbs) of the total N applied in July and again in August to support exponential fruit growth and summer vegetative shoot growth. Because both the mature and setting crops are being fertilized at bloom until just before harvest of the mature crop, trees will be receiving the extra N required during the period of full bloom, fruit set, and vegetative shoot growth (~April). A similar approach can be used for other nutrient elements in addition to N. Since fruit number drives the uptake of many essential nutrients, matching fertilization rates and application times to periods of high demand by the fruit, as well as periods of strong canopy growth (vegetative and floral shoot growth) and root growth is a sound approach to fertilization based on tree physiology, fertilizer-use efficiency, cost to benefit, and protection of the environment.

### *We are all in this together*

In this day of social networking, it is hoped that growers will share their experiences implementing these strategies, and others, and the outcomes obtained. Until quantitative data is available, grower experience will be invaluable and it might prove to be the best means to gain knowledge that adequately reflects the differences in tree architecture and yield potential under the various growing conditions and management practices used in avocado production in California.

† Phenological stages are provided when possible to assist growers in understanding the timing of developmental events independent of the effects of local climates. Months, typically provided in parentheses, are approximations of when phenological events occur but unfortunately are not applicable to all avocado-growing areas of the state of California.

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